The American Midland Naturalist

Devoted to Natural History, Primarily that of the Prairie States

Founded by J. A. Nieuwland, C.S.C.

Contents

Stratigraphy and Structure of the Area of Disturbed Ordovician Rocks near Kentland, Indiana—*Robert R. Shrock* 471

Paleontology of the Disturbed Ordovician Rocks near Kentland, Indiana—*Robert R. Shrock* and *Gilbert O. Raasch* 532

Skull of Musk-Ox, Genus Symbos, from Montgomery County, Indiana—*Marcus Ward Lyon, Jr.*, and *Fred T. Hall* 608

Ectoparasites of the Blunt-Nosed Minnow (Hyborhynchus notatus)—*John D. Mizelle* 612

The Genus Graminella (Homoptera-Cicadellidae)—*Dwight M. DeLong* and *Carl O. Mohr* 622

Evolutionary Trends, Ecological Notes, and Terminology of the Large-Winged Mites of North America—*Arthur Paul Jacot* 631

Diatoms from Lake Michigan—I.—*B. V. Skvortzow* 652

An Occurrence of Sphaerotheca lanestris in Mexico—*G. M. Watkins* and *C. H. Muller* 659

Phytosociological Studies in the Pinelands of Southeastern Louisiana—*William T. Penfound* and *Allan G. Watkins* 661

Three New Plants from Texas and Mexico and Some Recent Additions to the Texan Flora—*Paul C. Standley* 683

Book Reviews 685

Vol. 18 JULY, 1937 No. 4

EDITORIAL STAFF

THEODOR JUST,.....*Botany (Ecology, Taxonomy)*
Editor, University of Notre Dame

CARROLL LANE FENTON,.....*Invertebrate Paleontology*
West Liberty, Iowa

JOHN HOBART HOSKINS,.....*Botany (Morphology, Paleobotany)*
University of Cincinnati, Cincinnati, Ohio

REMINGTON KELLOGG,.....*Vertebrate Paleontology and Zoology*
U. S. National Museum, Washington, D. C.

MARCUS WARD LYON, JR.,.....*Mammalogy*
South Bend, Indiana

FRANCIS JOSEPH WENNINGER, C.S.C.,.....*Invertebrate Zoology*
University of Notre Dame

NOTE:—THE AMERICAN MIDLAND NATURALIST, published from the biological laboratories of the University of Notre Dame, is primarily, though not exclusively devoted to the Natural History of the Middle West. A wide selection of papers on botany, paleontology and zoology is published in bi-monthly issues, six of which make up a volume.

Fifty reprints will be furnished free of charge to contributors. Additional reprints should be ordered when proof is returned and may be had at cost price.

The following numbers are out of print: vol. 2, (1-3, 8-10); vol. 3, (1-3, 5-12) index, title page; vol. 4, (1-7) index, title page; vol. 6, (5, 8) index, title page; vol. 9, (9); vol. 10, index, title page; vol. 11, (1, 8). All others available, 30 cents per copy. Complete volumes: $3.00; volumes 7, 13, and 14, $1.50 each; vol. 15 $2.00, single issues 35 cents; vol. 16 $3.00, single issues 50 cents; vol. 17 $4.50, part 1 $2.00, nos. 2-6 50 cents each; vol. 18 $3.00, single issues 50 cents.

Exchanges for journals, special volumes or duplicate books, and specimens, should be arranged directly through the editorial office at the University of Notre Dame, where subscriptions also are received. Offers should accompany request for exchange.

For citation use this abbreviation: *Amer. Midl. Nat.*

Entered as second-class matter at Notre Dame, Indiana. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

The American Midland Naturalist

Published Bi-Monthly by The University of Notre Dame, Notre Dame, Indiana

VOL. 18 JULY, 1937 No. 4

Stratigraphy and Structure of the Area of Disturbed Ordovician Rocks near Kentland, Indiana

Robert R. Shrock

Introduction

The area to be discussed lies in northwestern Indiana, about 3 miles east of Kentland in Southern Newton County (Fig. 1). Here, in less than one-half a square mile, three quarries reveal over 350 feet of intensely faulted Middle Ordovician strata ranging in age from Prairie du Chien to Galena. Stratigraphical and structural problems of this highly disturbed complex have been discussed briefly in recent reports by Shrock and Malott (1933, 337-370) and Bucher (1935, 1055-1084). The former reported that the Middle Ordovician rocks have been uplifted about 1,500 feet, and that the

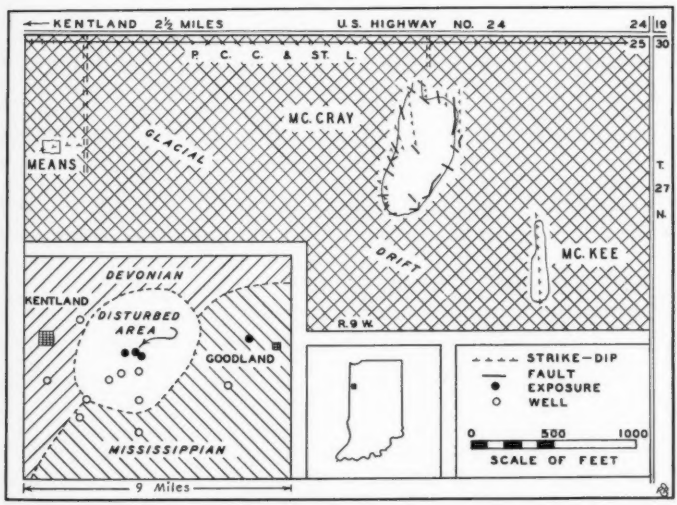


Fig. 1. Map of the quarry district 3 miles east of Kentland, Newton County, Indiana, showing structure and general geology.

disturbance, which faulted and shattered the rocks, is best interpreted as "cryptovolcanic."

This report presents the data upon which those articles were based, corrects several minor errors, and adds some new observations. Previous work on the area is reviewed; a generalized stratigraphic column is constructed; the several divisions are characterized lithologically and faunally; detailed sections, on which the generalized section is based, are described and the contained faunas are listed; and structural features of the area are discussed in order to clarify the nature and cause of the deformation.

Location and Geologic Setting

The quarry district lies in the N. half of Sec. 25, T. 27 N., R. 9 W., along the south line of Newton County, and approximately 3 miles east of Kentland (Fig. 1). U. S. Highway 24 bounds the area on the north. Exposures are limited to the quarries and their immediate environs. The westernmost opening is known as the Means quarry; the easternmost, as the McKee quarry. Both are shallow (3 to 10 feet) and abandoned, though strata are quite accessible. The McKee quarry is the one commonly mentioned in the older reports. The large middle opening, long known as the McCray quarry, is now generally called the Kentland quarry. It is operated by the Newton County Stone Company. In the following discussion the name McCray is used.

Outcrops are rare in the flat glacial plain which surrounds Kentland. In the quarry district, drift varies from 0 to 35 feet in thickness. Originally, the rock outcrops formed a low, broad mound on the prairie-like glacial plain, but quarrying has modified the countryside considerably (Fig. 4). According to Gorby (1886a, 235):

> "The surrounding country is covered with Drift to a great depth. A mile away from the quarries on the north it is 150 feet down to the rock. In the vicinity of Kentland the Drift is near 100 feet thick. At Mr. McKee's residence, 200 yards east of the quarry, it is 15 to 30 feet down to the rock. Two miles south, on the farm of Mr. Schlautenhofen, just on the edge of Benton County, the Drift is more than 100 feet thick. The simple presumption would be that this great mass of rock is merely a portion of greater masses that escaped the destroying influences of advancing glaciers, and the erosions and disintegrations of time. However, the glaciers have evidently enveloped it; they have passed round and over it, but the mass remains as a monument of greater forces that were in existence at a period antedating the glacial period."

Recent data support Gorby's statements and show that there must have been a prominent rock mound east of Kentland when the first Pleistocene glaciers slowly transgressed northern Indiana. Striations indicate that the ice came from the northward.

All the quarries originally were opened in natural outcrops, but in the large McCray quarry excavation has been so extensive that the edges of the present opening show much drift on the bed rock (Figs. 3, 4). Natural exposures may still be seen, however, for some distance north of the McKee quarry and for a short distance east of the Means quarry (Fig. 1).

Argillaceous Mississippian dolomite once was quarried from a shallow

opening northwest of Goodland, and along Pine Creek in Benton County (Gorby 1886, 206-208). With the exception of these exposures, and a few others only a few feet in thickness, the flat glacial plain surrounding the quarry district is unbroken by bedrock exposures for many miles (Shrock and Malott: 1930, 226).

Well data indicate that Devonian black shale lies north and west of the mound of Ordovician rocks; that possibly Pennsylvanian, though more likely Devonian or Mississippian, rocks lie to the south; and that Mississippian strata lie to the east. Were the glacial drift stripped off, therefore, the Ordovician mass would appear as an inlier.

Review of Previous Work

Until the biohermal or reef nature of the quaquaversal "domes" occurring in and along the upper part of the Wabash River valley in northern Indiana was established by Cumings and Shrock (1927, 1928), the structural complex at Kentland was generally believed to have the same origin as the "domes." Regardless of how they interpreted the "domes," however, nearly all investigators realized that diastrophic movements must have been responsible for the deformation of the strata at Kentland. If their suggestions appear overly cautious or novel, it is probably because, until the last two or three decades, Indiana was generally believed to be a state in which there had been little or no disturbance of the strata, least of all in the northern part.

After the biohermal nature of the "domes" became known, the Kentland complex aroused new interest, and numerous investigators visited the three quarries. Papers dealing specifically with the Kentland strata are based on observations made chiefly during the last decade.

Attention was first called to the disturbed condition of the strata east of Kentland by Collett (1883, 58-59), who wrote:

> Three and a half miles southeast of Kentland the rocky beds come to the surface, or nearly approach it, over an area of more than 100 acres. At one of these exposures the bedding is nearly horizontal—at the other, in close proximity, the rocks were in nearly a vertical position, with a north-south trend, showing either serious dislocations or deposition under circumstances which gave origin to the most pronounced false bedding.
>
> At the latter station the stone was a slightly crystalline, bluish-gray limestone, with great nodules of *cone-in-cone* one to two feet in diameter, indicating a pressure of superimposed material while it was in a plastic condition.
>
> At the time of my first visit, accompanied by Assistant George K. Greene, after a most careful and thorough search, not a single fossil, or fragment of a fossil, was found which could determine the age of these rocks.

On a subsequent visit, Mr. Greene was able to find, at one of these—McKee's quarry (Sec. 25, T. 27 N., R. 9 W.)—some slabs, containing the following fossils:

> *Tetradium fibratum, Zygospira modesta, Streptorhync[h]us, Leperditia, Ptilodictya, Orthoceras* and fragments of stems of *Glyptocrinus.*
>
> These fossils indicate that the rocks are Silurian, and probably of Lower Silurian [Ordovician] age. The mass is too large to admit of explanation by its transportation

during the Ice period; while the uniform, undisturbed condition of the strata of this and the adjoining States will not allow the presumption of upheaval and such dislocation of strata as would account for these phenomena.

As shown by the bores reported [on pages 52-57)], it is surrounded to the north and west, and at levels 150 to 200 feet lower than this point, by later Devonian shales and limestones; on the south and east, still at a lower level, are the rocks of the Keokuk Group of the still later Carboniferous age.

This quarry is a mystery. Its investigation invites and will reward the future geologist, who may be enriched with better light than is now available. At present the only explanation which can be here given is that once the Silurian rocks of this and adjoining regions may have been built up to a thickness of 200 or 300 feet more than they are at present, and that eroding forces at the close of the Silurian age removed all the upper beds of that age to a depth of 200 or 300 feet, leaving this small area an immovable island in the surging waters, and afterwards the later Devonian and Carboniferous beds were deposited around and against the sides of this monumental island.

Gorby (1886, 205-212), discussing the geology of Benton County, which lies just south of the quarry district, reported Mississippian rocks along Pine Creek (Sec. 24, T. 25 N., R. 7 W. and Sec. 28, T. 26 N., R. 7 W.), listed a number of well sections, and stated that coal had been reported from the Schlautenhofen farm in Sec. 1, T. 26 N., R. 9 W. He appeared to doubt that coal underlay Benton County, and later investigators have expressed the same opinion. Exposures on the McKee farm were mentioned (p. 211), and "According to Prof. Collett, the stone at the McKee quarry is classed by Prof. James Hall, of New York, as Silurian."

In the same year Gorby (1886a, 228-241), erroneously assuming a similar origin for the Kentland diastrophic complex and the quaquaversal reef structures of the upper Wabash valley and the Chicago district, postulated a narrow arch ("The Wabash Arch") extending in a northwest-southeast direction across northern Indiana, starting near the Ohio line and continuing by way of Chicago to the Lake Superior region. This arch, supposedly composed of Niagaran rocks, was attributed to an upheaval which probably "occurred while great masses of the Upper Silurian [Silurian] deposit were yet in a plastic condition, which is evidenced by frequent and large impressions termed *cone-in-cone*, caused probably by an upward pressure of the substrata."

Gorby (1886a, 235-237) described the countryside as it appeared at the time of his visit and called attention to the inclined strata in the Means and McKee quarries. From the latter he reported *Orthoceras simulator, O. annulatum, Gyroceras* (or *Lituites*) and *Orthis testudinaria*. These fossils confused him, for he stated:

While but few fossils have been found in the rocks here, and those that have been found conflict in their testimony in regard to the formation, some being Upper and others Lower Silurian, the general tendency of the evidence is such as to establish the belief that the formation is Upper Silurian [Silurian]. All those fossils that are imbedded in the rocks, whose characteristics are well enough preserved to admit of identification, are readily recognized as fossils common in the Niagara rocks. It would be difficult to account for the presence of these firmly imbedded in the rocks of the Hudson River or Trenton period. On the other hand, the Lower Silurian [Ordovician] fossils found are of the most delicate forms and lightest character, such as

would readily be carried upward through rents or crevices by the force of escaping steam or gas, such as would accompany an upheaval of the character indicated by the evidence all along the Wabash Valley.

Concerning the fossils found at the McKee quarry, Gorby wrote (p. 236):

> There are also several sepcies of Lower Silurian [Ordovician] fossils found in this quarry, consisting of delicate bryozoans, or the thin single values [valves] of *Orthis testudinaria*. These are invariably found in the seams between the layers of stone, attached slightly to the sides of the strata by a calcareo-argillacious cement. They are never found imbedded in the stone. They have evidently been carried up through crevices in the rocks by the force of escaping steam or gas from below.

In summarizing Gorby's observations, we must remark that recent geological work has shown that his postulated "Wabash Arch" does not exist; that careful search by several investigators has failed to produce a single Silurian fossil from any of the rocks in the quarry district; that the same species, which are Ordovician only, are found imbedded in both the layers and argillaceous films between the strata, so that it is unnecessary to call on escaping gases to get the fossils where they are now found. Furthermore, there is every reason to believe that the strata were hard and brittle, rather than in a plastic condition, when they were deformed.

Orton (1889, 580), commenting on the "Wabash Arch," thought that the irregularities described by Gorby ". . . include unequivocal examples of uplift and also unmistakable cases of false bedding on a large scale," but he apparently did not accept the postulated arch, for Thompson (1889, 41) reproached him for objecting to the name "Wabash Arch." Thompson (1889, 41-53) also made an impassioned plea for Gorby's postulated structure, repeating errors already committed and adding several. He described the deformation of the rocks well, however, when he stated (p. 44): "The whole rock mass has the appearance of having been subjected to a squeezing process at the time that it was being thrust upward by an expansive force from below. The arrangement of the structural elements of the rock shows the combined effects of these two agencies: compression from the side and perpendicular thrust from below." Thompson (1892, 182-185) repeated his arguments in favor of the "Wabash Arch" in a later article but added little that was new.

Phinney (1891, 620-621, 623) published a geological map of Indiana which shows Devonian black shale surrounding the quarry district east of Kentland. Several dotted circular lines circumscribe the area, but no other formations are indicated. He, like his contemporaries, thought that, "The strata of the State [Indiana] have never been greatly disturbed, and, except in a few gentle swells and broad arches, the rocks lie today nearly as they were originally deposited." Concerning Gorby's hypothetical "Wabash Arch" Phinney (1891, 652) stated, ". . . not a single observation indicates the existence of any such upheaval, arch, or anticlinal; indeed, the evidence all points in the opposite direction."

Gorby's (1892) geological map of Indiana, included in the 17th Ann. Rept., Ind. Dept. Geol. and Nat. Res., shows the Kentland area surrounded completely by Silurian.

In his classic report on the coal-bearing strata of Indiana, Ashley (1899, 184-191), using field data acquired by C. E. Siebenthal, listed well records from the Schluttenhofen basin in northern Benton County, where seams of coal had been reported. He thought the data uncertain, however, and left open the question of whether or not workable coal was present in the area. Concerning the steeply inclined strata in the quarry district, he wrote: "The rocks are limestones of Niagara age. From the radiating direction of the dips it would almost seem as though volcanic or other agencies had produced an upheaval of a kind seldom found in nature."

Kindle (1903, 459-468), as a prelude to his discussion of the so-called "domes" of northern Indiana, reviewed the work which had been done on these structures up to 1903, and pointed out that the explanations thus far given for the high dips were in error because of the prevailing opinion that the strata of that part of the state had not been disturbed. In commenting on the highly inclined strata at Kentland, (1903, 460) he observed: "Deformation alone offers a satisfactory explanation of such dips." Because he failed to recognize the Ordovician age of the rocks at Kentland, referring them to the Niagaran instead, and also because he erroneously assumed that the strata there owed their inclined attitude to the same cause which produced the quaquaversal dips along the Wabash, most of Kindle's conclusions are not now acceptable.

In his discussion of the Niagaran strata of northern Indiana, Kindle (1904, 401-428) included most of what appeared in his 1903 article, and added a more detailed description of the Kentland complex. Although he reported fossils in the Means quarry, he still referred the fossiliferous strata to the Niagaran, though all the fossils which have been collected subsequently show that the beds are of Ordovician age. In a companion report dealing with the paleontology of the northern Indiana Niagaran, Kindle and Breger (1904, 470-471) described and figured a new cephalopod, *Orthoceras (Kionoceras) kentlandense*, from Kentland, but did not state where it was collected.

Blatchley's geological map of Indiana (1904) showed southern Newton County as Silurian; this error was repeated by Logan (1922). In 1932, however, Logan (1932) left the quarry district east of Kentland blank, apparently being unwilling to accept the Ordovician age of the strata.

Until 1906, geologists disregarded Greene's discoveries of 1881, as reported by Collett (1883), and referred the Kentland rocks to the Niagaran (with the possible exception of Gorby (1886, 236-237). In that year, however, Greene (1906, 11-17) in a fiery article produced photographic evidence to support his earlier discoveries, reviewed the work of his predecessors, pointed out what he considered the absurdity of some of their conclusions, and criticized Gorby, Thompson and Kindle for not recognizing the Ordivician age of the strata. His Plate A (p. 16), showed slabs collected from the McKee quarry. They were photographed and the genera were identified by R. S. Bessler,[1] though

1 R. S. Bassler, personal communication, October 14, 1935.

Greene did not acknowledge this assistance. The fossils listed are *Leperditia fabulites, Escharopora, Rhinidictya, Leperditella* and *Helopora.* A cephalopod —*Poterioceras kentlandense*— from the same quarry also was illustrated. On the basis of these fossils Greene correctly assigned the strata of the McKee quarry to the Ordovician. Yet another 15 years were to pass before Foerste (1921, 277-278) corroborated Greene's conclusions.

During the interim, Ward (1906, 216), reporting on the road materials of Newton County, referred the Kentland strata to the Niagaran and pictured the three quarries lying on the flanks of an east-west, bean-shaped structural ridge. "This ridge, of Niagara limestone, offers a rather complex problem; but it seems that it is a synclinal fold, much broken in the folding. This view is borne out: (1) By the dip of all exposed strata on the north side of the ridge being north or northwest, and the dips of all those on the south side being to the south or southeast; (2) By the abruptness of the edge of the field beyond the limits of the ridge, and (3) by the uniform thickness of the drift (20 to 40 feet) on all sides of the elevation." One of Ward's (1906, 219) analyses (of specimens from the McCray quarry) shows a limestone with a rather small amount of magnesium carbonate.

Foerste (1921, 277-278), referred the Kentland rocks to the Ordovician (Black River) because *Columnaria halli, Rafinesquina minnesotensis, Strophomena trentonensis, Zygospira recurvirostris, Ctenodonta nasuta, Actinoceras beloitense, Isotelus* cf. *platycephalus* and *Thaleops ovatus* were collected from a brownish-gray, fine-grained limestone "resembling some phases of the Plattin limestone of eastern Missouri." Foerste did not state whence these specimens came, and he did not collect at Kentland, but the fossils almost certainly were collected in the McCray quarry.

Since Foerste's report, the Kentland rocks have been mentioned frequently. Cumings (1922, 419-420, 449) accepted their Ordovician age and predicted that an understanding of them would shed "new light on the question of the origin of the 'Niagara domes'." He (1922, 449) was certain that "the presence of Ordovician strata in the Kentland dome also indicated that the structures are genuinely diastrophic or vulcanic and involve not only the Niagaran rocks but the underlying formations. The possibility of cryptovolcanic action, such as described by Bucher. . . in an area near Cincinnati, Ohio, should not be overlooked in any further study of these domes." The confusion of the Kentland structure with the "domes" is apparent in this statement, but Cummings later took the lead in clarifying this confusion.

Logan (1922a, 949-950) apparently overlooked the literature which Cummings (1922) had reviewed, for he stated: "The subsurface of Newton County is occupied by the strata of the Silurian in the central portion and northern portion of the county and by the Devonian strata in the southern portion of the county. The strata of the northern portion dip north and those of the southern portion toward the south." He (1922a, 950) reported an important well record at Kentland, which shows the stratigraphic sequence underlying that town, and which follows:

Record of well at Kentland

Drift	100	feet
Black shale (New Albany)	100	"
Corniferous (Devonian)	45	"
Niagara limestone	305	"
Hudson River limestone	300	"
Utica shale	210	"
Trenton limestone	60	"
Total depth	1120	"
Elevation of Kentland	681	"
Elevation of top of Trenton	379	" below sea level.

In later articles Logan (1926, 340-341; 1931, 450-451) apparently disregarded recent discoveries, for in 1926 he made essentially the same statement as the one quoted above, and in 1931 he stated that: "In the southern part [of Newton County] there is a small area of bedrock belonging to formations perhaps older than the Silurian, as in the quarry east of Kentland." He also mentioned that: "A small area in the southern part [of Newton County] east of Kentland has a domed area in which the beds are tilted at high angles." In his recent Geological Map of Indiana, Logan (1932) left blank the quarry district east of Kentland, though the legend, prepared by Malott, shows the formations present in the quarries.

Chamberlin (1923, 217-218) used the Kentland structure to illustrate intense crustal shortening, in discussing the crustal shortening of the Colorado Rockies, and stated: "Some two miles east of Kentland, in the plains of northeastern [northwestern] Indiana, the limestone beds exhibit a very sharp, narrow-crested anticlinal fold whose limbs reach the surprising inclination of over 80° (Fig. 2).[2] The *percentage* of shortening involved in this small, sharp anticlinal fold in the interior plains is much greater than that involved in the great Rockies of Colorado, but the *actual amount of crustal shortening* in the little fold is very small in comparison. A comparison of the Kentland fold with the Colorado Rockies on the basis of percentage of shortening, would be likely to be very misleading in tectonic studies." Dr. Chamberlin has subsequently discussed the Kentland structure with the author and believes that it is a fault of probable cryptovolcanic origin.

Cumings and Shrock (1927, 71-85), after briefly reviewing previous work in northern Indiana, presented evidence for the reef origin of the famous quaquaversal "domes" and pointed out that the "high dips at Kentland, sometimes as much as 90 degrees, are due to faulting and associated crumpling, as outcrops now visible clearly show, and are not related in origin to the dome-like structures found elsewhere in the northern part of the state." (p. 71). In their report on the Silurian of northern Indiana they (1928a, 137) stated: "We are not prepared to offer any final theory of the origin of the complicated structure at Kentland, where middle Ordovician strata are brought to view. Even a cursory examination shows that there has been considerable faulting and crumpling. The broken condition of the strata is

2 Chamberlin's Fig. 2 shows nearly vertical beds, apparently in the north part of the McCray quarry.

well shown in the southwestern corner of the present quarry [McCray], east of Kentland. . . This structure is in no way analogous to the reef structures discussed below; although it was for a long time thought to be similar in origin to the 'domes' along the Wabash Valley. The Kentland structure is apparently of diastrophic or vulcanic origin, as suggested by the senior author (1922, 449), and later by Chamberlin (1923, 217), and may be the result of crypto-volcanic action." It was also reported that the senior author had found Ordovician fossils in the McCray quarry.

Reeves (1925, 322), discussing oil production in northern Indiana, stated: "At certain points on and near the crest of the Cincinnati anticline, on which the Trenton field is located, unusual quaquaversal folds are known to exist, concerning which little is known. Three of these prominent folds are found near Wabash, Huntington, and Kentland. In these localities the glacial drift is thin or absent and parts of the structure may be seeen, although outcrops are not sufficiently abundant to permit detailed surface mapping. Dips as great as 20° are found on the flanks of these folds, and the rocks in their centers are considerably older than those flanking the sides." Here again is the unwitting confusion of reef structures and the Kentland complex.

Ver Wiebe (1929, 688-689) apparently overlooked the several articles which showed that the "domes" and the Kentland structure were not genetically related, because in discussing the unconformity at the top of the Trenton limestone of Indiana, he wrote:

> In a few areas near Wabash, Huntington, and Kentland in Indiana, however, the drift is thin or absent. There the outcrops of Ordovician rocks show the limestones standing at fairly high angles (up to 20°). Furthermore, the rocks differ considerably in age from place to place. These facts seem to indicate that diastrophism may have been much more effective during the latter part of the Ordovician period than we have generally believed or known.

Shrock and Malott (1930, 221-222) briefly described the Kentland complex as follows:

> The strata are inclined at high angles, in some places closely approaching verticality, and the strike of the upturned layers is far from uniform especially in the south half of the [McCray] quarry. . . . The structure in these quarries has resulted from intense deformation by both folding and faulting. Rocks are exposed here which in nearby localities, in some cases less than three miles, are 1,500 feet beneath the surface. Such structure, occurring as it does in a region of flat-lying rock remote from known areas of intense deformation, is very surprising. . . . Mr. Shrock has already identified 14 species, in addition to those listed by Greene and Foerste, from the westernmost [Means] of the three quarries, and all are typical forms in the Black River-Trenton series of Minnesota. The strata in the two abandoned quarries [Means and McKee] have been found to be the same. It is almost certain that they represent rocks of Black River-Trenton age, and it is also very likely that rocks of the same age occur in the larger active quarry [McCray].

In a later paper Shrock and Malott (1933, 337-370) gave a more detailed account of the stratigraphy and structure and listed a fauna of over 75 species. The essential features of the complex were noted and the strata were reported to have been uplifted about 1,500 feet by a disturbance of cryptovolcanic nature.

Shrock and Raasch (1935, 355-356) correlated the Ordovician section

at Kentland with strata in Tennessee and the upper Mississippi valley, and concluded that the Platteville of Wisconsin is pre-Lowville—an opinion which now seems to be doubtful.

The latest comments on the Kentland complex appeared in an article by Bucher (1935, 18-20) dealing with cryptovolcanic structures in the United States. These comprise a brief summary of the salient stratigraphical and structural features of the complex, and were based on a short paper prepared by the present writer.

In summary, it would be unfair to geologists who have discussed the Kentland strata, were the writer to fail to point out the several handicaps under which most of them worked. First, they avoided a diastrophic interpretation because of the general belief that the strata of Indiana had never been greatly disturbed. Second, with this belief destroyed but with the reef nature of the "domes" along the Wabash still unknown, most investigators erroneously assumed that, since the strata at Kentland and those surrounding the reefs were steeply inclined, they must have reached that attitude through the action of similar forces.

Stratigraphic Sequence Exposed in the Quarries

The general stratigraphic sequence exposed in the 3 quarries east of Kentland shows 12 divisions. These divisions, which are indicated in Plate 1, are now described in detail and where possible are correlated with formations in other areas. The detailed sections on which these divisions are based will be discussed fully a little later.

Division 1. (Prairie du Chien)

1. Limestone, highly dolomitic: gray-buff, finely crystalline, fairly thin-bedded (1″-4″), containing considerable clastic quartz, numerous small siliceous oölites, and a few white, oölitic chert nodules. Some layers have oölites only; some have only quartz grains; and some have both. Thickness 6 feet.

The strata of this unit comprise a fault block in the extreme southeastern corner of the McCray quarry (Plate 3), directly, above and south of an exposure of fossiliferous sandstone. The block is separated from the sandstone to the west by a covered interval of several feet, and can not be seen in actual contact with any of the surrounding blocks, though it is known to have fault contacts with them. The greatest thickness that can be assigned to the unit is 6 feet, though it is possible that some of the dolomitic limestone lying along the northern boundary of the sandstone mass may belong to this unit.

In the dolomite are several thin bands of siliceous oölites, and a similar band is associated with the greenish shale exposed in a small ravine cut into the sandstone mass some distance to the west. The scattered oölites appear to be original, since no other part of the limestone is replaced by silica. Many of them have quartz cores, indicating that much of the internal part of the original oölite crystallized. (Plate 2, Figs. 1-3).

PLATE 1

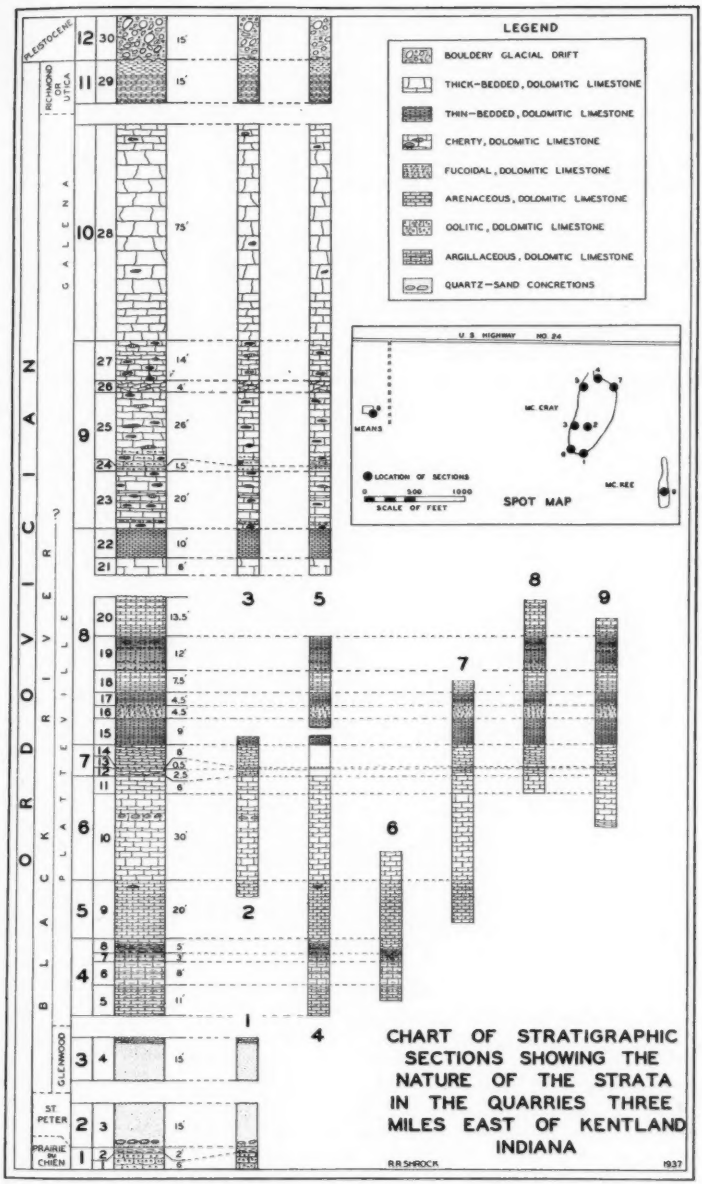

LEGEND
BOULDERY GLACIAL DRIFT
THICK-BEDDED, DOLOMITIC LIMESTONE
THIN-BEDDED, DOLOMITIC LIMESTONE
CHERTY, DOLOMITIC LIMESTONE
FUCOIDAL, DOLOMITIC LIMESTONE
ARENACEOUS, DOLOMITIC LIMESTONE
OOLITIC, DOLOMITIC LIMESTONE
ARGILLACEOUS, DOLOMITIC LIMESTONE
QUARTZ-SAND CONCRETIONS
U. S. HIGHWAY NO. 24
MEANS
MC. CRAY
MC. REE
LOCATION OF SECTIONS
SCALE OF FEET
SPOT MAP
PLEISTOCENE
RICHMOND
UTICA
GALENA
PLATTEVILLE
ST. PETER
PRAIRIE DU CHIEN
GLENWOOD
BLACKRIVER?
ORDOVICIAN
CHART OF STRATIGRAPHIC SECTIONS SHOWING THE NATURE OF THE STRATA IN THE QUARRIES THREE MILES EAST OF KENTLAND INDIANA
R.R. SHROCK
1937

PLATE 2

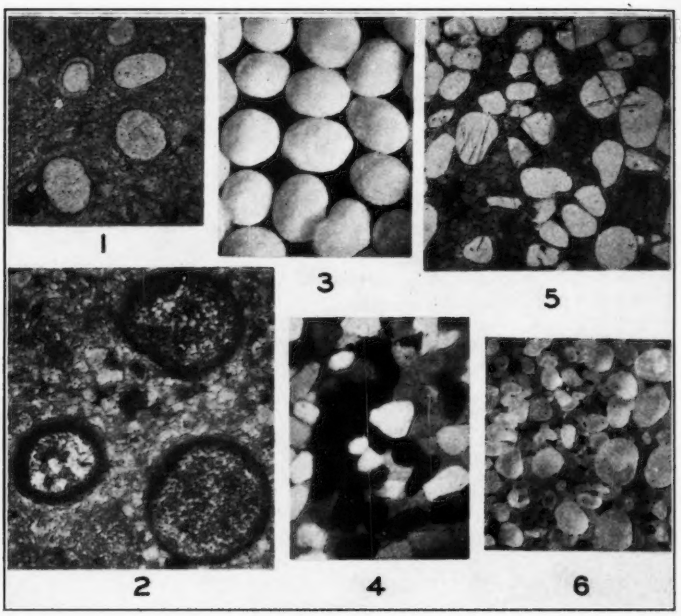


Fig. 1. Thin section of oölitic limestone from Div. 1 (1), with ordinary light (x8). Fig. 2. Thin section of oölitic limestone from Div. 1. (1), with crossed nicols, showing the siliceous shell and crystalline quartz core of several oölites (x20). Fig. 3. Siliceous oölites, such as are shown in 1 and 2, freed from their calcareous matrix (x12). Fig. 4. Thin section, with nicols crossed, of a calcite-bound sandstone layer from the upper part of Div. 4 (8) (x8). Fig. 5. Thin section of a typical specimen from Div. 5, with ordinary light, showing the rounded quartz grains held in a calcareous matrix. Some of the larger grains are fractured (x12). Fig. 6. Detrital quartz grains from Div. 5, after being freed from the rock, such as shown in 5, by solution of the calcareous matrix. Note the rounded and frosted condition of the larger grains (x8).

2. Shale: gray and buff-green to robin's egg blue, laminated, containing a number of small, white, oölitic chert nodules. It appears to grade into the adjacent sandstone. Thickness 2 feet.

This shale becomes very sticky when wet and quickly breaks down into greenish mud. In recent years it has been exposed in a small ravine eroded into the sandstone mass about in the middle of the exposure (Plate 3). Several years ago the exposure showed the shale closely folded into a syncline and anticline, both pitching southward into the quarry wall, but this exposure is no longer visible. In the present exposure the shale is closely associated with dark-brown, oölitic dolomite similar to that included in unit 1.

Correlation.—Division 1 is correlated with the highest beds of the Prairie du Chien group on the basis of its oölitic nature and its association with a sandstone considered to be in part correlative with the St. Peter. It is possible, however, that future work may show the sequence to be the basal portion of the St. Peter sandstone.

Division 2. (St. Peter)

3. Sandstone: white, quartzose, with bedding largely obliterated, highly fractured because of the intense shearing of the rock, and cut by a complex system of fractures which cause the rock to separate into irregular blocks bounded by shear planes. The grains, where not crushed, are fairly well rounded, especially in the larger sizes, and show some secondary enlargement. Thickness estimated at 15 feet, though probably more.

The entire thickness of sandstone exposed in the south wall of the McCray quarry was originally thought to be St. Peter, but recent study of stratigraphic relations and the discovery of a fauna in part of the sequence make it advisable to divide the sandstone into two parts, the lower correlated with the St. Peter sandstone, the upper with the Glenwood sandstone and shale of Illinois.

That part of the sandstone considered equivalent to the St. Peter is composed of well rounded and frosted quartz grains which range from 0.1 to 1.0 mm. in diameter, with the average about 0.35 mm. The rock has been so severely crushed that most grains have been fragmented, ground to smaller size, or granulated: mechanical analysis is impossible. In the sandstone which lies next to the green shale already described under Div. 1, the bedding appears to strike in a general east-west direction and to dip northward very steeply. In the lower 5 feet of the mass are numerous discoidal concretions of uncrushed quartz grains, cemented by iron oxide. These concretions vary in diameter from 1 to 3+ inches and are fairly firmly cemented. Cutting the sandstone near the shale outcrop are several vertical fractures, along which are many limonite shells full of softer limonitic material. Some phases of the sandstone are fairly coarse-grained, especially near the shale contact; but there are also very fine-grained, pure phases which probably belong to the St. Peter. The latter texture characterizes the polyhedral blocks, bounded by shear planes, into which the rock breaks before disintegrating into incoherent sand.

The estimated thickness of this division is 15 feet, a figure based on the assumption that parallel banding of the sandstone next to the shale exposure in the small ravine is bedding. Since the discoidal concretions lie along these bands, which parallel laminations in the shale, there is good evidence that banding does indicate bedding. About 15 feet of the sandstone appear to be bedded, but it is almost certain that the division is considerably thicker.

This division is best exposed in the south wall of the McCray quarry, where it is flanked on the east, north and west by dolomitic limestone, and on the south by a mantle of glacial drift (Plate 3). In several other places, however, small masses of the sandstone have been caught up and crushed

together with other rocks. Such masses occur just south of the black shale exposure, in the southeastern corner of the quarry and a few feet above its floor, and in the southwest corner of the quarry just north of the prominent fault zone. The latter mass is a part of a very extensive brecciated zone and is close to a crystalline dolomitic limestone containing *Cryptophragmus*. Because it sheared easily, the sandstone underwent intense crushing during the deformation and may be expected to occur along any zone of extensive faulting or brecciation.

Correlation.—Div. 2 is correlated with the St. Peter sandstone of the upper Mississippi valley because of its lithological nature and purity (the Glenwood has considerable argillaceous content), its lack of fossils (fossiliferous sandstone layers are referred to the Glenwood), and its stratigraphic relations (contiguity with shale and oölitic dolomite believed to represent the highest beds of the Prairie du Chine group). From the sequence exposed in the Kentland quarries, it is difficult to correlate this formation with any saandstone other than the St. Peter.

Division 3 (Glenwood)

4. Sandstone: white, quartzose, with bedding mostly obliterated, highly fractured, fossiliferous. The rock is rather fine-grained though somewhat less so than some phases of the St. Peter; large grains are well rounded. This unit contains a few thin (2″-3″) beds which are highly fossiliferous. The fauna, chiefly molluscan, is Platteville in character; hence the sandstone is correlated with the Glenwood shale and sandstone of Illinois and Wisconsin. Thickness approximately 15 feet.

This sandstone contains argillaceous material. It lies along the northwest, north and northeast borders of the main sandstone mass, describing a rough semi-circle about the latter, and because the beds dip steeply toward the floor of the quarry, they appear to lie on a broad dome of which the central part may be the ravine where the green shale, presumably at the base of the St. Peter or the top of the Prairie du Chien, is exposed. Lying against the sandstone of this unit, but separated by faults, are several masses of buff, dolomitic limestone thought to belong somewhere in Div. 4, but of uncertain stratigraphic position because of its lack of fossils. Since the fossiliferous zone in this unit can not be seen in contact with overlying beds, its position in the sequence is uncertain, but it probably lies at or very near the top of the unit and is so indicated in Plate 1.

The thickness of this unit is uncertain because neither top nor base is exposed. From areal distribution (bedding is obscure and uncertain) a thickness of 15 feet is assigned the sandstone though this figure is little more than a guess.

The fauna of this division contains several molluscan and 2 arthropod genera:

Liospira sp.
Endoceras sp.
Modiolopsis (2 species)
Orthodesma sp.
Sphenolium sp. (n. sp.?)
Tripteroceras sp. (n. sp.?)
Leperditia fabulites
Ceraurus cf. *pleurexanthemus*

These fossils are sand fillings of the shell interiors or impressions and occur in a fairly fine-grained phase of the sandstone.

Correlation.—Division 3 is correlated with the Glenwood shale and sandstone of Illinois and Wisconsin on the basis of lithology and fauna.

Concealed Zone between Divisions 3 and 4

Since the lowest beds of Div. 4 are cut off by faults and the top of Div. 3 is uncertain, it is impossible to determine the magnitude of the concealed interval between unit 4 of Div. 3 and unit 5 of Div. 4. Several years ago, 29 feet of argillaceous and dolomitic limestone were exposed along the north border of the sandstone mass about in the middle of the exposure (Plate 3). Shrock and Malott (1933, 352) considered this section immediately to overlie the Glenwood phase of the sandstone, but recent observations make this conclusion uncertain. Since the block has been quarried away, its relations to the adjacent sandstone are doubtful.

Division 4 (Platteville)

5. Limestone, dolomitic: light-buff, fine-grained and chalky, in thin (1″-3″) beds which are separated by even bedding planes and characterized by smooth fracture. The entire sequence, as well as units 6 and 7 above, are cut by many fractures which lie normal to the bedding, and in the southwestern corner of the McCray quarry dip southward at an angle of about 30°. These fractures, which are related to deformation of the beds, cause the rock to separate into pencil-like fragments and platy chips which weather yellowish-buff. Fossils are rare.

Thickness at least 11 feet and probably nearly 20 feet.

The rock, apparently unfossiliferous, is well exposed in the southwestern corner of the McCray quarry, where at least 6 feet of bedded stone fade into a much fractured mass of the same lithology which extends eastward at least 5 feet before disappearing under talus and drift. It was also once present in a large fault block along the north wall of the same quarry just east of the ramp (Plate 3 and Fig. 3), but this section of rock has been quarried away recently. Here the thickness was at least 11 feet, but a fault terminated the section so the complete thickness was not determined. Some of the light-buff, dolomitic limestone lying along the north border of the large sandstone mass may belong to this unit.

6. Limestone, dolomitic: blue to buff, fine-grained, much fractured in the same manner as unit 5; layers 6″-30″ thick. The rock is somewhat argillaceous and shatter cones are abundant. Fossils are rare. Thickness 8 feet.

This sequence occurs in the southwestern corner of the McCray quarry (Plate 1, column 6; Plate 3; and Fig. 4) and once was present in the north wall of the same quarry.

7. Limestone, dolomitic: buff or dark-buff, fine-grained, thinly (4″-12″) and irregularly bedded, much fractured and full of shatter cones. The rock is somewhat lighter-colored in its lower part. No fossils were noted. Thickness 3 feet.

8. Limestone, dolomitic: sandstone; and shale, arenaceous: their sequence

consists of thin (2″-4″) layers of impure, arenaceous dolomitic limestone (Plate 2, Fig. 4) alternating with dolomitic and argillaceous sandstone and arenaceous shale. An 8-inch quartzitic layer lies about a foot below the top of the sequence. Since layers are of variable resistance, the sandstone and shale weather away more rapidly and leave the more resistant dolomitic layers as nearly vertical ribs in the wall. The entire unit is intensely shattered. Fossils are rare. Thickness approximately 5 feet.

The sequence is present in the southwestern corner of the McCray quarry (Plate 1, column 6; Plate 3; and Fig. 4) and was once exposed in the north wall of the same quarry, a few rods east of the ramp (Plate 3 and Fig. 3).

Correlation.—Very few fossils have been found in Division 4. *Leperditia fabulites* and *Ceraurus* have been found in both underlying and overlying divisions, showing that the beds between should probably be considered as upper Glenwood or lower Platteville. For the present, Div. 4 will be included in the Platteville because of the dominance of dolomitic beds, but the division might be referred to the upper Glenwood, since the sequence appears to be transitional from Div. 3 to Div. 5. Some of the species of the "molluscan fauna" may have come from this division, though it does not seem probable.

Division 5 (Platteville)

9. Limestone, somewhat dolomitic and highly arenaceous: blue-gray to light brown, dense, even-textured, fine-grained to semi-lithographic, in heavy (6″-36″) beds with stringers and lenses of clastic quartz grains. There are also a few layers of somewhat granular, fossiliferous dolomitic limestone, and some in which the rock has a spotted appearance due to granular masses set in a very dense matrix. The former appear as thin layers of comminuted shells and several of them have convex brachiopod valves oriented in such a way that the convexity indicates the upper side of the layer (Plate 4, Fig. 6). Fucoidal stems ramify through some beds; when weathered free from the surrounding lithographic limestone, they comprise a tangled network of solid rods. These are especially characteristic of the upper layers which are spotted because of their presence. There are a few white chert nodules, 2″-4″ across, in the upper 3 feet. The lower 5-7 feet are fossiliferous, slightly argillaceous, somewhat thinner bedded than the remainder of the unit, and contain little clastic quartz except in the lower foot or so. It is thought that some of the species of the "molluscan fauna" came from this unit.

Some grains of the clastic quartz sand in this unit are arranged in thin lenses and stringers; some are disposed in sinuous rod-like aggregations suggesting the trails of burrowing organisms; some are sprinkled sparsely throughout the thick beds. These grains, held in a firm calcareous matrix (Plate 2, Fig. 5), are well rounded, especially in the larger sizes, and are frosted (Plate 2, Fig. 6). Many of them fall apart upon release from the matrix, splitting along the fractures which were imposed on them when the strata were deformed (Plate 2, Fig. 5). Many grains exhibit undulatory extinction under crossed nicols, indicating a strained condition which must be attributed to the stresses which deformed the rocks. The distribution of the

sand through the unit is variable. Some beds have no grains, whereas others carry as much as 45% by weight. Mechanical analyses of about 100 grams of the sand, removed from the limestone by acid treatment, showed it to be excellently sorted and to have a size range from 0.1 mm-1.0 mm, with the average grains about 0.30 mm. in diameter (Fig. 2).

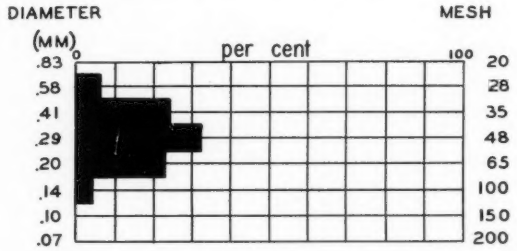


Fig. 2. Histogram of about 100 grams of clastic quartz sand obtained by acid treatment of typical limestone from Division 5. The excellent sorting is obvious.

Fossils, chiefly convex valves of *Rafinesquina minnesotensis,* occur sparingly throughout the arenaceous part of the division. In the lower 7 feet of the unit, however, in beds with little or no clastic quartz, Shrock and Malott (1933, 354-355) reported a rich molluscan fauna from the north wall of the McCray quarry. This fauna was collected from talus which had accumulated at the base of a large fault block composed chiefly of Divs. 4-6, and this talus material was assumed to have come from the aforementioned block. This fauna, of which some specimens are known to have come from Div. 6, includes the following:[3]

"Molluscan Fauna" Divs. 4-6

Nicholsonella pulchra (in Div. 5 only)
Pholidops trentonensis minor
Valcourea deflecta
Pionodema cf. *conradi*
Rafinesquina minnesotensis
Rafinesquina n. sp.
Strophomena platlinensis
Strophomena platlinensis crassa var. nov.
Rhynchotrema minnesotense
Zygospira saffordi
Ctenodonta cf. *levata*
Ctenodonta cf. *logani*
Ctenodonta ovata robusta (in Div. 6 only)
Ctenodonta socialis
Ctenodonta nasuta (horizon uncertain)
Cyrtodonta billingsi
Cyrtodonta cf. *huronensis*
Vanuxemia rotundata
Vanuxemia decipiens kentlandensis var. nov.
Vanuxemia sulcata sp. nov.
Ambonychia cf. *attenuata*
Clionychia triangularis sp. nov.
Tetranota wisconsinensis
Salpingostoma buelli
Phragmolites grandis
Raphistomina cf. *modesta*
Lophospira conradana
Lophospira oweni kentlandensis var. nov.
Lophospira perangulata
Lophospira serrulata
Lophospira sexlineata sp. nov.
Liospira progne

3 This "molluscan fauna" is believed to have come from Divs. 4, 5 and 6, and the species are so located in Part II of the present report. Future discoveries may prove this assumption incorrect, and may show that the fauna lies higher or lower stratigraphically.

Liospira obtusa
Liospira vitruvia
Eotomoria trochoides sp. nov.
Clathrospira subconica
Hormotoma gracilis angustata
Eccyliopterus aff. *beloitensis*
Eccyliomphalus undulatus
Holopea ampla
Stenotheca kentlandensis sp. nov.
Hyolithes baconi
Salterella billingsi
Pterotheca expansa
Pterotheca cf. *attenuata*
Pterotheca intermedia sp. nov.
"*Orthoceras*" cf. *sociale*
Kionoceras kentlandense (horizon uncertain)
Actinoceras beloitense (horizon uncertain)
Kentlandoceras shrocki
Tripteroceras indianense sp. nov.
Isotelus gigas
Thaleops ovatus
Ceraurus bispinosus
Ceraurus pleurexanthemus
Leperditia fabulites

Division 5 is exposed in the southwestern corner of the McCray quarry (Plate 3), in the central part of the quarry near the sump, and in the northeastern corner where the nearly vertical, heavy beds have been abraded into prominent roches moutonnées. Formerly, strata of this division were present in a large fault block in the north wall just east of the ramp, but that section of rock has been quarried away. The distinctive lithology of this unit should identify it in well cuttings if such ever become available in the Kentland vicinity.

Correlation.—Division 5 is considered a part of the Platteville formation because of its fauna and stratigraphic position. This correlation is doubly certain if the rich molluscan fauna from the north wall of the McCray quarry belongs at this level.

Division 6 (Platteville)

10. Limestone, dolomitic: light brown to buff, fine-granular and fairly even-textured, in thick (4″-24″) beds, usually weathering to a "sandy" condition and a dark buff color. About 22 feet above the base is one bed which contains numerous large, white, lenticular chert nodules. The upper 8 feet above the cherty horizon consist of alternating, inch-thick bands of buff, granular, dolomitic limestone and gray, dense, stone which give the weathered rock a horizontally banded appearance. Throughout the unit the bedding planes are much pitted and there is some shale, possibly the result of intraformational solution, between the beds. The rock is much shattered and contains numerous shatter cones. A cephalon of *Thaleops ovatus* was found in one of the beds, but no other fossils were noted, though some of the species common in the molluscan fauna from the north wall of the McCray quarry may also occur in this unit (see discussion concerning Div. 5). Thickness 30 feet.

This unit is extensively exposed in the disturbed area, being present in all the quarries. It is exposed along the south wall of the Means quarry and along the west wall of the McKee, at the south end. In the McCray quarry (Plate 3), part or all of the sequence is exposed in the northeastern corner; in the central part of the quarry just northeast of the sump; and in the southwestern corner where the beds appear to form a westward-pitching syncline cut off to the north by a fault. The beds of this unit were once exposed in the north wall just east of the ramp, but most of the sequence has been

removed. The large fault block once present in about the middle of the south wall may have been composed largely of this unit, though this seems rather unlikely.

11. Limestone, dolomitic: buff to gray, granular, fucoidal, fairly heavy-bedded (2″-36″), weathering to a "sandy" condition and characterized by thin, crinkly partings of black, carbonaceous material between the layers, which have roughly etched and pitted bedding planes. When weathered, the rock becomes somewhat porous and light buff. No fossils were noted. Thickness 6 feet.

Beds belonging to this unit appear in all three quarries. In the Means quarry they lie along the south wall and in the McKee, along the west wall at the south end. In the McCray quarry, the unit is exposed in the northeastern corner and at the sump in the floor of the quarry (Plate 3). The ramp also seems partly to cover this unit in the north wall of the quarry.

In an isolated fault block along the east wall of the McCray quarry, there was exposed in the summer of 1932 a buff or brownish, dolomitic limestone which contained a fauna coming apparently above that of Div. 5. This fauna resembles the Upper Buff fauna of Wisconsin, probably comes from the upper part of Div. 6 or from Div. 8, and contains:

Streptelasma profundum
Hesperorthis tricenaria
Valcourea deflecta
Ctenodonta gibberula
Ctenodonta ovata robusta
Omospira cf. *alexandra*
Lophospira serrulata
Liospira sp.
Ophiletina sublaxa
Trochonema cf. *umbilicatum*
Hyolithes baconi
Pterotheca intermedia sp. nov.
Pterotheca cf. *attenuata*
Spyroceras cylindratum
Encrinurus sp.
Ceraurus pleurexanthemus
Calyptaulaux sp.
Leperditia fabulites

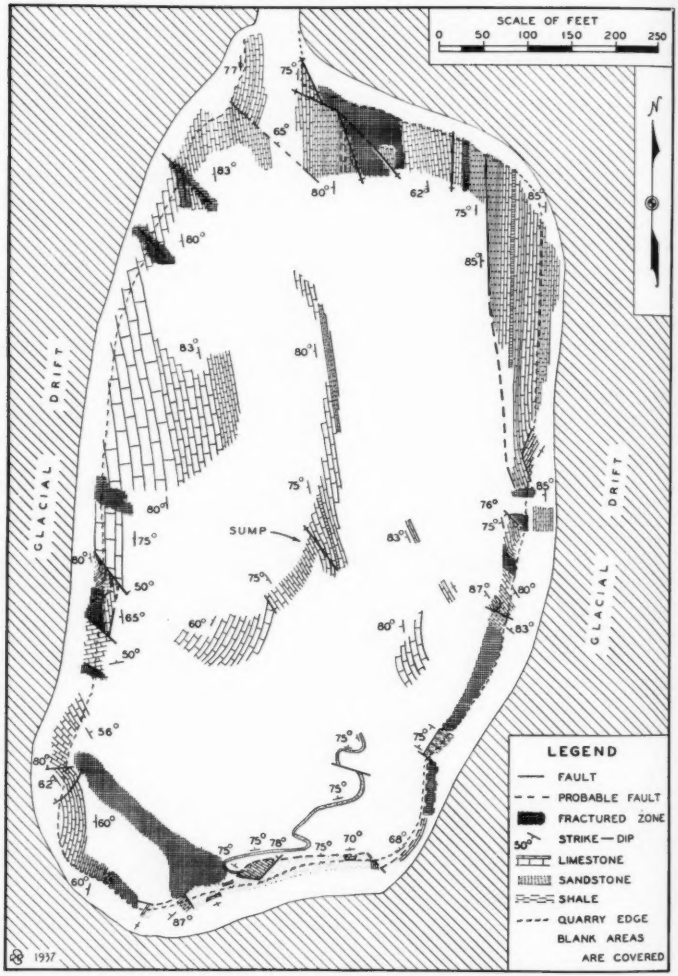
Correlation.—Division 6 is included in the Platteville because it lies below the typical Carters stromatoporoid fauna of Div. 7. The fauna of the division is too sparse to warrant further statement of stratigraphic position, unless some of the species of the "molluscan fauna" occur in this division. If they do, Div. 6 (like 4 and 5) certainly is of Platteville age.

Division 7 (Carters)

12. Limestone, somewhat dolomitic: gray to brownish, moderately granular, heavy-bedded (6″-16″), with layers separated along very rough surfaces by thin, crinkly films of black, argillaceous material, and full of well preserved colonies of *Cryptophragmus antiquatus, Kentlandia imbricata* gen. and sp. nov., and *K. irregularis*. sp. nov. The lower 6 inches are a coquina of these fossils. Thickness 2.5 feet.

This distinctive fossil zone is present in all the quarries. The beds forming the south wall of the Means quarry are full of stromatoporoids, and some poorly preserved specimens of *Cryptophragmus* occur in the south end of the McKee quarry. In the McCray quarry, the zone is especially well exposed at the sump, in the central part of the quarry floor (Plate 3), where fossils are abundant. The zone also is present in several small fault blocks in the north-

PLATE 3



Geological Map of the McCray Quarry, 3 miles east of Kentland, Indiana, showing structure, extent of exposure, and different rock types. Much of the quarry floor is covered with debris which conceals underlying strata.

eastern corner of the quarry, and probably occurs beneath the crushed stone of the ramp. The zone was well exposed along the quarry wall in the northeastern corner, but recent excavation has removed most of it. Some blocks of this unit have been caught up in the broad brecciated zone in the southwestern corner of the quarry (Plate 3), where they are associated with sandstone from Div. 2 or 3, and with limestones from Div. 9.

13. Limestone, somewhat dolomitic: gray, semi-lithographic, very thin-bedded (0.5″-2″), with the layers separated by paper-thin films of black and greenish shale. No fossils noted. Thickness 7 inches.

Unit 13, conspicuous amid heavy beds, is best exposed at the sump in the central part of the McCray quarry (Plate 3), but also occurs in the northern part of the same quarry at several points, and in the Means and McKee quarries as well.

14. Limestone, dolomitic: light brown to gray, semi-lithographic, even-grained, smooth-fracturing, thin-bedded (1″-12″), its solution-etched bedding surfaces separated by crinkly films of black, carbonaceous shale. Tiny, crystalline stringers and small calcite rods which may represent fossils are abundant throughout. There are a few fucoidal zones, and the upper 2 feet consist of alternating gray, dense dolomitic layers and thin layers of coarser and darker, irregular bands. There is a thin (1″-2″) bed of intraformational breccia about 5 feet below the top of the unit. Evidence of intraformational solution along the bedding planes is abundant throughout the unit.

Fossils are numerous, including *Cryptophragmus antiquatus, Kentlandia imbricata* gen. and sp. nov., *K. irregularis* sp. nov., *Rhynchotrema minnesotensis, Liospira* sp., *Leperditia fabulites* and *Bumastus milleri.*

This zone is present along the south wall of the Means quarry; in the McKee quarry along the north wall of the large pit at the south end of the opening; and in the McCray quarry at the same places as unit 12.

Correlation. Division 7, the *stromatoporoid* zone, is correlated with the Lowville of New York and the Carters (= Lowville) of Tennessee on the basis of *C. antiquatus* which is recognized as one of the typical guide fossils of that stratigraphic horizon.

Division 8 (Black River)

15. Limestone, somewhat dolomitic: bluish-gray, white-weathering, semi-lithographic, thin-bedded (0.5″-2″) and fossiliferous, with the thin layers separated by films of black or gray, somewhat carbonaceous shale. Many

The strike-dip symbols show the inclination of the beds and faults, but only in continuous sections do the figures indicate the true dip of the beds, for elsewhere in the quarry it was impossible to determine tops and bottoms of beds. Unless otherwise indicated, the faults are vertical or very steeply inclined. Most of the smaller faults that parallel or cross the bedding are not shown, because their displacement rarely exceeds a few inches. The numerous fracture zones are zones along which movement as well as fracturing have taken place. The quarry is a fault mosaic with the intensest disturbance in the southern third. This map represents a revision of the map published by Shrock and Malott (1933). C. A. Malott, R. Bates and W. L. Wilgus assisted in field work.

small bryozoans, brachiopods, and ostracods are attached to the upper sides of the thin layers, but usually are not apparent until the shale film has been removed. Thickness 9 feet.

The fauna of this fossiliferous unit includes the following species:

Cryptophragmus antiquatus
Kentlandia imbricata sp. nov.
Rhinidictya exigua
Rhinidictya mutabilis
Rhinidictya trentonensis
Escharopora angularis
Escharopora recta
Escharopora subrecta
Helopora alternata
Helopora mucronata
Helopora spiniformis
Helopora pulchella sp. nov.
Crania seligera
Hesperorthis tricenaria
Rafinesquina cf. *hermitagensis*
Zygospira recurvirostris
Isotelus gigas
Ceraurus dentatus
Calyptaulax cf. *eboraceus*
Leperditia fabulites
Leperditella persimilis
Leperditella sulcata
Leperditella tumida
Eurychilina subradiata
Eurychilina ventrosa
Drepanella crassinoda
Krausella arcuata

Unit 15 occurs in all the quarries (Fig. 1). In the McCray quarry, it appears at the sump and in the northeastern and northwestern corners (Plate 3).

16. Limestone, somewhat dolomitic: gray, semi-lithographic, thin-bedded (1″-4″), containing abundant fucoids which, when the rock is freshly broken, give it a spotted appearance, and on weathering cause the rocks to be pitted. There are numerous small, unidentified ostracods near the top of the unit. Thickness 4.5 feet.

Unit 16 has the same distribution as 15.

17. Limestone, somewhat dolomitic: buff-gray, semi-lithographic to granular, thin-bedded (1″-3″), bearing *Tetradium cellulosum* and *Zygospira recurvirostris* along bedding planes. The bedding surfaces are somewhat etched by weathering and intraformational solution. There are several thin layers of comminuted shells, too thoroughly broken for identification. Thickness 4.5 feet.

The fauna includes *Tetradium cellulosum, Rhinidictya mutabilis, Zygospira recurvirostris* and *Leperditella persimilis.*

Unit 17 is present in all the quarries. In the McCray quarry it is exposed at the sump and in the northeastern and northwestern corners (Plate 3).

18. Limestone, dolomitic: buff to brown, finely crystalline, thin-bedded (2″-4″) and with irregular separation planes. The rock has irregular fracture and is full of shatter-cones. There are a few layers of chocolate-colored, lithographic stone which weathers white and contrasts sharply with the dark buff color of the "sandy" crystalline beds. Fossils similar to those in units 16 and 17 occur sparingly. Thickness 7.5 feet.

This unit has the same distribution as units 16 and 17.

19. Limestone, dolomitic: bluish-gray, white-weathering, semi-lithographic, thin-bedded (1″-4″), fucoidal, the fucoids being abundant throughout massive beds and concentrated in numerous thin layers. Transverse sections

of the fucoidal bundles resemble the cross-section of a large, flattened cable. The fucoids give the weathered rock a "birds'-eye" appearance. A few nodules of white chert in the upper 2 feet lie within the beds as well as along the separation surfaces and are rarely more than an inch across. No fossils other than fucoids were noted. Thickness 12 feet.

In the Means quarry, unit 19 lies in the northeast corner; in the McKee it lies along the east wall; and in the McCray it is present in the northeastern and northwestern corners and possibly also at the sump, but at the latter place the beds are disturbed and their relations are uncertain.

20. Limestone, dolomitic: buff-brown, finely granular and fairly heavy (4″-8″) beds alternating with thinner layers of gray, semi-lithographic rock full of fucoids; no other fossils were noted. The total thickness could not be determined because the overlying strata are either covered, as in the Means and McKee quarries, or faulted out as at several points in the McCray quarry. The measured thickness is 13.5 feet.

This unit forms the northern wall of the Means quarry and the eastern wall of the McKee quarry, and occurs at the sump and in the northwestern corner of the McCray quarry.

Concealed Interval between units 20 and 21.—Faulting interrupts the succession of Div. 8 between units 20 and 21, hence the magnitude of the concealed interval between these two units is uncertain. Available evidence, suggests that the interval does not greatly exceed a few tens of feet.

21. Limestone, slightly dolomitic: light gray, very finely crystalline and even-textured, and in a single massive bed. No fossils noted. Thickness 6 feet.

This massive bed forms the base of a 100-foot section along the western wall of the McCray quarry and occurs again along the north wall of the same quarry.

22. Limestone, somewhat dolomitic: blue to gray, very dense, lithographic, thin-bedded (1″-3″), separating readily into layers which have slightly undulating surfaces and are separated by wavy films of black carbonaceous shale. The fracture is conchoidal and the rock tends to break into blocks about an inch long. No fossils or chert were noted. Thickness 10 feet.

This unit is present in several small fault blocks along the northern wall of the McCray quarry and again in the northwestern corner where its full thickness is not present because of faulting. Along the west wall it forms the basal part of thick sequence of northward dipping beds. It contrasts sharply to the darker and heavier bedded strata with which it is associated.

Correlation.—Units 15 to 22 inclusive are grouped into Div. 8 because of similar rocks and faunas, and because chert nodules are absent from all units except 19. Lithic alternations give this sequence unity and distinguish it from underlying and overlying divisions.

On the basis of the fauna listed above and in the faunal table, Div. 8 is referred to the Black River, its lower part being correlated with the Platteville of Wisconsin.

DIVISION 9 (BLACK RIVER—TRENTON)

23. Limestone, dolomitic: brown and dark gray, heavy-bedded (6″-36″), cherty, and with much textural variation. Some beds are brownish, splotched, and are finely crystalline. Others are gray, semi-lithographic and tend to become somewhat thinner bedded. Beds 2.5-3 feet thick, when blasted from the quarry face, break into large blocks which separate on weathering into thinner beds. Fucoidal zones and bands are numerous, and layers of comminuted shells occur. While fucoids of Div. 8 are seldom larger than the lead of an ordinary pencil, those of Div. 9 are as large as the pencil. The entire unit is characterized by large, white chert nodules and lenses within layers and along separation planes. They rarely exceed 4 inches in thickness but may be several feet long. Silicified colonies of *Columnaria* are very common and numerous molluscan shells (represented by fillings) occur in some beds. Thickness 20 feet.

This unit is limited to the western wall and northwestern corner of the McCray quarry. Its fossils include *Columnaria halli, Ctenodonta* sp., *Lophospira* sp., *Subulites* sp., *Hormotoma* sp. and several genera of orthoceratite cephalopods.

24. Limestone, dolomitic: bluish-gray, irregularly textured, somewhat argillaceous, fucoidal, the small fascicles of fucoids resembling cross sections of flattened cables. Several orthoceratite cephalopods were found. Thickness 1.5 feet.

Unit 24 occurs in several fault blocks along the west wall and in the northwestern corner of the McCray quarry.

25. Limestone, somewhat dolomitic: light brown and gray, semi-lithographic or fine-granular, fairly thick-bedded (6″-24″), cherty and fossiliferous. The chert nodules are brown when fresh but white when weathered, average about 3 inches thick and are a few inches to 3 feet long, and lie within the layers as well as along the etched bedding planes. There are numerous 4″-12″ fucoidal layers of blue, somewhat argillaceous and dolomitic limestone. These are especially abundant in the lower 10 feet. The lower 2 feet are cherty and chocolate-colored. Throughout the unit are occasional layers characterized by irregular masses of coarse-grained material. Stylolites are common along the bedding surfaces and associated with them are many films of black, argillaceous material which probably are a result in part of the solution which produced the stylolites. Silicified colonies of *Columnaria* occur throughout the unit and are associated with numerous poorly preserved mollusks. Thickness 26 feet.

Unit 25 is limited to the northwestern part of the McCray quarry where it occurs in several fault blocks.

26. Limestone, slightly dolomitic: gray, very dense, lithographic rock fracturing conchoidally and characterized by very irregular bedding planes which cause the layers to take a lenticular form. The beds, which are 2 to 6 inches thick, are separated by crinkly black films of carbonaceous shale. Some

of this argillaceous material is almost certainly the result of solution. No fossils were noted. Thickness 4 feet.

This distinctive zone, along which there has been some shearing (made especially easy by the brittle nature of the rock) is limited to the west wall and northwest corner of the McCray quarry (Plate 3).

27. Limestone, dolomitic: brownish-gray, semi-lithographic and fairly heavy-bedded (6″-24″), with many white chert nodules and numerous silicified colonies of *Columnaria* and occasional shells of *Leperditia*. The rock consists of a dense matrix containing many irregular masses of coarser grained material. Thickness 14 feet.

Unit 27 is exposed along the west wall and in the northwest corner of the McCray quarry (Plate 3).

Correlation.—Units 23-27 inclusive are grouped into Div. 9 because of similar lithology and abundance of chert throughout them. *Columnaria* is the only common fossil, and occurs in all the units except 26.

Division 9 is provisionally placed in the Black River-Trenton because of its stratigraphic position above the fossiliferous beds of Div. 8 and below Div. 10 which is believed to be equivalent to the Galena of Wisconsin.

Division 10 (Galena)

28. Limestone, dolomitic: dark-gray, porous and granular, heavy-bedded (6″-36″), consisting of alternating thin bands of slightly varying texture. These bands are separated by paper-thin films of black carbonaceous shale, possibly the result of intraformational solution; when the rock is weathered, its streaked appearance is conspicuous. The weathered rock also tends to effloresce and to become intensely fractured, the latter characteristic apparently being due to shattering imposed during deformation. The rock of the lower 14 feet is somewhat saccharoidal and is full of colonies of a small, silicified, vermiform bryozoan. No other fossils were noted. Chert nodules are few. The thickness is at least 75 feet, for that much has been measured, and it probably exceeds 100 feet. The highest beds of the unit show fault contacts with contiguous and adjacent rocks; hence the nature of the immediately overlying strata is not known, except for the black shale of Div. 11 which is considered to be younger.

This unit is exposed along the north and west walls and in the northwest corner of the McCray quarry in a number of fault blocks. The fault block once present in the middle of the south wall of the McCray quarry may have represented a sequence at the very top of unit 28, since a somewhat comparable sequence, representing the highest beds of the unit, occurs along the west wall of the same quarry.

Correlation.—Division 10 (unit 28) is provisionally correlated with the Galena dolomite of Illinois and Wisconsin on the basis of lithic similarity and position above typical Black River-Trenton strata.

Division 11 (Utica or Richmond)

29. Shale, calcareous and limestone, argillaceous: black to dark gray, thin

laminated, calcareous shale and argillaceous dolomitic limestone, in alternating thin beds averaging 4-6 inches thick. The rock is pyritiferous throughout and intensely shattered; a short period of weathering reduces it to a talus of small blocks and chips. There are no fossils. A thickness of 15 feet can be measured, but the total appears to be considerably more.

The rock of Div. 11 (unit 29) exhibits three lithic phases. (1) Adjoining the fault plane which cuts off the shale mass of the west wall on the north side, and presumably at the base of the sequence, since the shale mass comprises a westward-dipping syncline (Plate 3), are 2-3 feet of olive-colored shale. There, thinly laminated shale breaks into tiny chips and plates, becomes sticky when wet, and slakes readily to mud. It contains many cubical crystals of pyrite, of which some are 0.5 inch wide. The shale is slightly gritty. (2) The main bulk of the shale mass is black, calcareous (as much as 40% soluble in HCl) shale which breaks with conchoidal fracture into irregular chunks which when wetted divide into tiny chips. Some chunks break up into small, bullet-like pellets, while others separate into paper-thin laminae, and still others break like the "pencil" shales of the Pennsylvanian of southwestern Indiana. Those phases of the shale which are the least calcareous slake to mud when wet, but fragments from highly calcareous beds retain their form. Cubes and small nodules of pyrite are scattered throughout this phase. (3) There are a dozen or more thin (0.5″-3″) layers of dark gray, very fine-grained argillaceous and dolomitic limestone in the shale mass. These are separated from the contiguous shale by sharp, smooth bedding planes, and lie from 8 to 12 inches apart (Plate 4, Fig. 4). Because of their lighter color, they are conspicuous in the black shale and give it a banded appearance. A few small pyrite nodules and cubes occur in some of the layers.

Division 11 is exposed in the east and west walls of the McCray quarry in the southern half (Plate 3 and Fig. 4). The block in the west wall has been exposed only a few months and appears to be a closely folded syncline pitching steeply westward into the wall. To the north and south, as well as underneath, the shale mass is crushed against heavy beds of dolomitic limestone along faults of unknown magnitude. The structure of the mass in the east wall is uncertain but appears to be a closely folded syncline, which dips into the wall. The adjacent rocks are faulted against the shale mass as along the west wall, and the boundaries are fault planes. Crushed into the underlying fractured limestones are several pockets of sandstone from Div. 2 or 3.

Correlation.—Division 11 is believed to lie above Div. 10 stratigraphically, because Divs. 10-9 comprise a continuous sequence and there is no shale horizon known in the lower beds to and through the St. Peter sandstone. Furthermore, the shale is so intimately associated with the beds of Div. 10 as to suggest that it once overlay those strata.

Assuming that the shale of Div. 11 is the youngest rock in the disturbed area, it probably is equivalent to the so-called "Utica" shales which have been reported frequently from wells in northern Indiana. There is also the possibility that this shale may be of Richmond age. Because of its uncertain position and age, the shale formation is placed at the top of the stratigraphic column, and is assigned an Upper Ordovician age (Plate 1).

Division 12 (Pleistocene)

30. Glacial till of Wisconsin age, composed of clay, sand, gravel and large boulders of acid and basic igneous rocks, resting on the smoothed but irregular rock surface, which the glacier abraded into roches moutonées in some places, and smoothed and striated to a flat plane elsewhere, across the ends of the vertical and steeply inclined beds. The thickness of the drift varies from 0 to 100 or more feet in some wells near the quarries. The drift thickens in every direction away from the quarry district, indicating that the ice moved over a rocky hill of considerable pre-glacial relief.

Stratigraphy of the Quarries

The size and relations of the Kentland quarries, the attitude of the strata in them, and the general geologic setting of the surrounding region are shown in Fig. 1. The sections exposed in the quarries will be described in detail below, since they have served as the basis for the generalized stratigraphic column of the disturbed area just discussed (See Plate 1). Faunal lists will be given for the several fossiliferous zones. The divisions, and units within the divisions, to which the various strata are referred will be indicated.

The McKee Quarry

The easternmost quarry at Kentland has been called the McKee, after the owner of the property on which it lies. It was visited and referred to by early investigators — Collett (1883), Gorby (1886, 1886a), Thompson (1889), Kindle (1903, 1904), Greene (1906) and Ward (1906). The quarry lies about 650 feet west of the town road along the east side of Sec. 25, T. 27 N., R. 9 W. and about one-fourth mile south of U. S. Highway No. 24. It is a long and rather narrow, dry excavation (Fig. 1) following the general strike of the beds. It is nowhere exceeding 80 feet in width and 15 in depth, and extends north and south, with interruptions, for about 650 feet. It may have been deeper when quarrying was going on (Gorby, 1886a 236).

Apparently the original opening was made in a natural exposure and natural exposures of the eastward dipping strata form narrow ribs parallel to the strike north of and along the east and west sides of the quarry. For some distance away from the quarry, yellow soil suggests that bedrock lies near the surface, but eastward and southward the surface of the bedrock descends. At Mr. McKee's house, some 250 yards southeast of the quarry and 25-30 feet below its floor, bedrock was encountered at a depth of 25 feet.

The strata strike generally north-south (N. 11° E. to N 22° W.) and dip eastward at 58°-72°. A transverse section of a weathered dolomite layer, in the northeastern corner of the quarry, exhibits clear cross-lamination etched into relief by solution, and shows that the beds are right side up, (their tops being toward the east). The strata are broken by inclined fractures, which dip northeastward at a lower angle than the bedding. Many of the thin layers show small displacements along the curved and grooved surfaces of the so-called "shatter-cones" (see later discussion of these features), which are variously oriented with respect to the bedding surfaces. Both fractures

and displacements are closely related to the stresses which deformed the rocks. Some of the former strongly suggest fracture cleavage.

The following section was measured from east to west across the upturned beds, and is generalized from the several exposures used. The figures represent true thicknesses.

SECTION IN THE MCKEE QUARRY, (DESCENDING ORDER)
(Column 9, Plate 1)

Division 8

20–18. Limestone, somewhat dolomitic: gray, white-weathering, semi-lithographic, thin-bedded (2″-6″), with a few small white chert nodules about 18 feet above the base. The beds are fucoidal in part and vary lithologically. Beds of brown, finely crystalline dolomite and thin layers of comminuted shells alternate with semi-lithographic rock. Incompletely exposed in the southern part of the quarry ---------- 25′

17. Limestone, dolomitic: gray, white-weathering, semi-lithographic, thin-bedded (1″-4″); bedding planes somewhat etched and covered by narrow colonies of *Tetradium* and other fossils ---------- 4.5′

16. Limestone, dolomitic: similar to rock above and below, but intensely fucoidal. The fucoids, when weathered out, leave vermiform tubes---- 4.5′

15. Limestone, somewhat dolomitic: gray, white-weathering, lithographic, thin-bedded (1″-4″), with marked conchoidal fracture and with shale films separating thin limestone beds. Fossils are numerous on the upper sides of the layers though usually are not apparent until the argillaceous covering has been removed. There are also a few thin lenses of comminuted shells and scattered fucoids. The unit is much fractured and breaks into small blocks an inch or more long ---------- 9′

Division 7

14–12. Limestone, dolomitic: brown, porous, fine-granular, fairly heavy-bedded (2″-12″), slightly fucoidal, and weathering to a "sandy" condition. Poorly preserved colonies of *Cryptophragmus* occur in this unit, which is only partly exposed. There is considerable drag folding and some cross faulting of minor character near the top of the unit ---------- 11′

Division 6

11–10. Limestone, highly dolomitic: brown to buff, fine-granular, and fairly heavy-bedded (6″-10″) rock alternating with light buff, fine-grained, thin-bedded (1″-2″) rock which breaks into thin chips and contains a few scattered fucoids. The beds, which are incompletely exposed, are found along the western wall at the south end of the quarry---------- 18′

Total ---------- 72′

The following species have been identified from the several units of the section (number in parentheses indicates unit).[4]

4 The species marked by an asterisk was reported and figured by Greene (1906). The supposed Silurian species, reported by Gorby (1886a, 236), are not listed because no subsequent visitors to the quarry have ever found a specimen of Silurian age. Collett's (1883, 58-59) list from the McKee quarry, identified by G. K. Greene, included *Tetradium fibratum*, *Zygospira modesta*, *Streptorhynchus*, *Leperditia*, *Ptilodictya*, *Orthoceras* and *Glyptocrinus*. When Greene (1906) listed the fossils he had found, he included *Leperditia fabulites*, *Escharopora*, *Rhinidictya*, *Leperditella*, *Helopora* and *Poterioceras kentlandense*. *Rhinidictya paupera*, reported by Shrock and Malott (1933, 346), was incorrectly identified and hence has been omitted.

(17) *Tetradium cellulosum*
(12–14) *Cryptophragmus antiquatus*
(17–18) *Rhinidictya mutabilis*
(17) *Zygospira recurvirostris*
(?) **Poterioceras kentlandense*
(12–14) *Leperditia fabulites*
(17–18) *Leperditella persimilis*

This small assemblage demonstrates the Ordovician age of the strata, and corroborates the findings of Greene, as reported by Collett (1883, 58-59) and later by Greene (1906) himself.

The Means Quarry

The westernmost, or Means Quarry, is so named because it lies on the Means homestead, about 2.5 miles east of Kentland. It lies about 210 feet west of the farm lane leading to the Means home, and approximately 700 feet south of U. S. Highway No. 24. The opening, now abandoned, dry and not more than 10 feet deep, is about 150 feet long in an east-west direction and about 70 feet wide. The bottom of the quarry is partly covered with soil which has washed in from the surrounding field, but there are good exposures along the west, south and east walls. The section given below was measured along the last two. There are also some small outcrops of rock, similar to the lithographic beds, east of the quarry between it and the farm lane (Fig. 1). Around the opening, yellow clayey soil, with many small limestone slabs, contrasts conspicuously with black silty loam of the surrounding prairie and presumably forms a thin covering over bedrock. North of the quarry, nearly to the railroad, the abundance of small limestone slabs in the soil strongly suggests that the underlying rock may form a north-south ridge under thin soil. East of the quarry, beyond the farm lane, yellowish soil and numerous small white limestone slabs suggest bedrock near the surface, and old inhabitants say that plows often bring thin limestone slabs to the surface.

In the quarry, where excavation has followed the strike of the beds (Fig. 1), and in the nearby outcrops to the east, the strata have a general east-west strike (E.-W. to N. 57° E.) and dip northward at angles which range from 51° to more than 70°. The beds are considered to be top side up because fossils occur on the north sides of the fossiliferous layers (See Shrock and Malott: 1933, 347, for details), and because the exposed sequence matches the section in the McKee and McCray quarries where the same beds are top side up.

Along the east wall of the quarry, a system of fractures lies normal to the bedding. Kindle (1904, 415) noted these: ". . . . a system of cleavage planes, somewhat resembling bedding, have been developed at right angles to the true bedding. They were doubtless developed by the pressure which produced the heavy dip seen here." The writer also relates the fractures to the stresses which tilted the beds.

The following section was measured along the east and south walls of the quarry, from north to south across the edges of the northward dipping strata. True thicknesses are given.

SECTION OF STRATA EXPOSED IN THE MEANS QUARRY,

(DESCENDING ORDER)

(Column 8, Plate 1)

Division 8

20. Limestone, dolomitic: poorly exposed zone of brown and gray, fine-granular, semi-lithographic rock with several prominent layers of fucoids. The beds in this unit lie near the surface and are thin (2″-6″) ---- 12′

19. Limestone, somewhat dolomitic: bluish-gray, white-weathering, semi-lithographic, fairly thin-bedded (2″-6″) and intensely fucoidal, with definite layers near the top in which the cross-sections of the fucoids resemble the ends of flattened cables. The rock weathers with a "birds'-eye" effect. Layers are separated by thin shale films which have digitate extensions into underlying layers. There are a few nodules of white chert, 1″-2″ across, in the upper 2 feet ---- 12′

18. Limestone, dolomitic: buff-brown, fine-granular, fairly thin- (2″-4″) and irregular-bedded, rough-fracturing rock containing a few thin layers of brown, semi-lithographic limestone. There are many small shatter-cones. 7.5′

17. Limestone, somewhat dolomitic: buff-gray, white-weathering, dense, thin-bedded (2″-6″), containing several thin beds of comminuted shells. Numerous colonies of *Tetradium* suggest equivalence with the *Tetradium* layer in the McKee and McCray quarries ---- 4.5′

16. Limestone, somewhat dolomitic: similar to contiguous beds, but intensely fucoidal; the top layer contains small, unidentified ostracods ---- 4.5′

15. Limestone, somewhat dolomitic: bluish-gray, white-weathering, semi-lithographic, thin-bedded (0.5″-3″) and fossiliferous, its thin layers separated by films of gray or black carbonaceous shale. Most of the fossils are attached to the upper surfaces of layers ---- 9′

Division 7

14–12. Limestone, dolomitic: brown-buff, fine-granular, "sandy"-weathering, thin- to fairly thick-bedded (2″-10″), rough-breaking; contains numerous colonies of *Cryptophragmus* and *Kentlandia* gen. nov. together with several other genera. About 5 feet from the top is a thin (1″-2″) zone of breccia, apparently intraformational rather than dynamic. About 8 feet from the top is a 6 inch bed of thin-laminated rock and directly beneath this zone is a 2.5 foot coquina of the two fossils mentioned above. This division has been identified in the other quarries ---- 11′

Division 6

11. Limestone, dolomitic: brown-buff, fine-granular, "sandy"-weathering; generally similar to overlying rock, but contains no fossils and is more heavily bedded. This rock can be seen south of the quarry approximately 6′

Total ---- 66.5′

The following species have been collected and identified from the Means quarry (numbers indicate the unit or units from which the fossils came).[5]

5 Two species, *Leperditella canalis* and *Primitiella simulans*, listed by Shrock and Malott (1933, 347) from the Means quarry, were incorrectly identified.

Rafinesquina minnesotensis is changed to *R.* cf. *hermitagensis.*

(17) *Tetradium cellulosum*
(14–12) *Cryptophragmus antiquatus*
(14–12) *Kentlandia imbricata* gen. and sp. nov.
(14) *Rhinidictya exigua*
(15) *R. mutabilis*
(15) *R. trentonensis*
(15) *Escharopora angularis*
(15) *E. recta*
(15) *E. subrecta*
(15) *Helopora alternata*
(15) *Helopora mucronata*
(15) *H. spiniformis?*
(15) *H. pulchella* sp. nov.
(15) *Crania setigera*
(15) *Hesperorthis tricenaria*
(15) *Rafinesquina* cf. *hermitagensis*
(14) *Rhynchotrema minnesotense*
(15) *Zygospira recurvirostris*
(15) *Isotelus gigas*
(14) *Bumastus milleri*
(15) *Ceraurus dentatus*
(15) *Calyptaulax* cf. *eboraceus*
(14–15) *Leperditella persimilis*
(15) *L. sulcata*
(15) *L. tumida*
(15) *Eurychilina subradiata*
(15) *E. ventrosa*
(15) *Drepanella crassinoda*
(15) *Krausella arcuata*

This fauna contains many species found in the Platteville of Wisconsin, but the majority of these are long-ranging forms; several others are post-Platteville in age. As a whole the fauna is of somewhat later age than the molluscan fauna of the McCray quarry, but earlier than the typical Guttenberg-Ion assemblage of the upper Mississippi valley region. The stromatoporoids comprise a unique and distinctive zone.

The McCray Quarry

The McCray quarry is the largest of the Kentland quarries, and has been operated for many years by the Newton County Stone Company. The following analyses, furnished by Mr. Virgin, one of the company's employees, show the chemical nature of five samples of rock from the quarry:

Number	SiO_2	$\frac{Fe_2O_3}{Al_2O_3}$	CaO	MgO	Naturalizing power as $CaCO_3$
1.	9.5	1.22	28.1	18.8	95.3
2.	5.35	.60	41.9	8.96	94.5
3.	3.04	.64	41.9	10.8	99.2
4.	9.81	.62	28.8	18.1	95.7
5.	1 8	.43	30.8	20.2	103.7

The present opening is roughly oval, with a maximum length of about 950 and a width of approximately 475 feet; depth ranges from 35 to 75 feet. For a few feet from the quarry walls, removal of drift has revealed the glacially striated edges of upturned strata (Plate 3). The glacier moved in a southerly direction and in some places plucked large masses, giving parts of the uncovered surface the appearances of roches moutonées. Much of the quarry floor is covered by crushed stone which conceals the underlying strata.

The McCray quarry presents several structural and stratigraphic problems. The exposed strata show intense deformation: dips range from nearly horizontal (rare), to vertical, or even overturned in a few instances. Bedding faults, thin brecciated zones parallel to and cutting across the bedding, shatter-cones variously oriented with respect to the bedding, and numerous other fracture phenomena, are characteristic. Folds are relatively rare, though sev-

eral prominent ones are closely associated with faults, while numerous small drag-folds accompany small faults which cut across the bedding.

Limestones, sandstones and shales were involved in the deformation and no two reacted in the same way. As a rule, the limestones broke and were fractured or faulted; the sandstones were shattered and granulated; and the shales were folded or faulted. All the rocks are much shattered, though the limestones have "healed" to some extent through recrystallization.

As a whole, the quarry is a complex fault mosaic, with the strata of the tilted blocks dipping steeply to the westward. The main movement appears to have been one in which the under beds moved upward with respect to the overlying strata, suggesting a localized upward thrust from below. The southern third of the quarry displays the most intense deformation. Plate 3 shows the geological aspects of the quarry; Figs. 3-5 are photographs of different parts of the quarry.

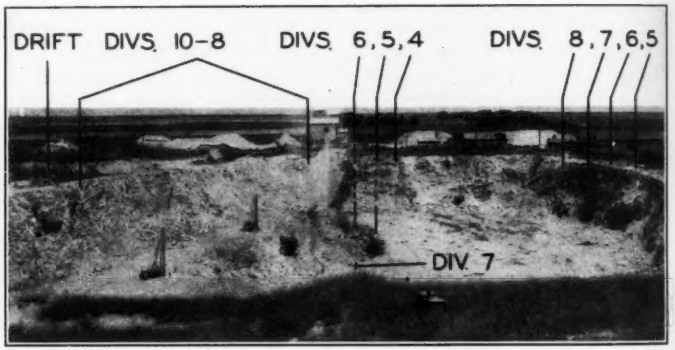


Fig. 3. View, looking north, of the northern part of the McCray quarry. Stratigraphic divisions are indicated. Note the mantle of drift surrounding the quarry and the flat glacial plain stretching into the distance. Photograph by F. T. Thwaites, June, 1932.

The south wall.—Along the south wall of the quarry, for 100+ feet in an east-west direction, a white, poorly cemented quartz sandstone is exposed in a 45-foot face (Plate 3 and Fig. 4). This large block, which is clearly bounded on the east and west, and very likely also on the north, by fault planes or zones, consists of two lithic facies: one relatively coarse-grained and unfossiliferous, the other relatively fine-grained and fossiliferous. The entire block is shattered by fractures and faults and the individual grains usually are cracked. Since the block is concealed to the southward by drift, its full dimensions are uncertain, and shattering makes the sequence represented somewhat doubtful.

What seems to be the lower part of the sandstone sequence, consists, where not crushed, of well-rounded and frosted quartz grains averaging about 0.35

mm. in diameter. Usually, however, the grains have been crushed and abraded by deformation until they have lost most of their original surface characteristics. Stratification is indistinct, so that estimates of thickness may involve considerable error. A zone of green and gray shale 3 to 6 inches thick, found interfolded with the sandstone in a small ravine near the middle of the sandstone block, suggests that the surrounding sandstone may also have been folded, providing another source of error in an estimated thickness of 15 feet. The lithological character of the coarser grained facies, and the relation it bears to associated strata, seem to justify its reference to the St. Peter sandstone of the Upper Mississippi Valley.

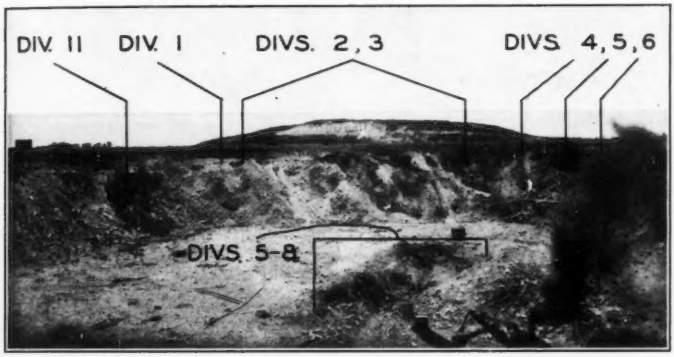


Fig. 4. View, looking south, of the southern part of the McCray quarry. Stratigraphic divisions are indicated. The ridge in the background consists of drift stripped from the quarry site. The depth of the quarry ranges from 30 to more than 60 feet. Phototgraph by F. T. Thwaites, June, 1932.

The part of the block which seems to be the upper part of the sandstone sequence exhibits crude bedding, is much finer grained than the lower facies (the individual grains average about 0.1 mm. in diameter, but there are also numerous rounded and frosted grains as much as 1 mm. in diameter), and contains numerous poorly preserved internal fillings of mollusk shells. These fossils were first discovered by Drs. Stark and Lamey in the fall of 1931, and later were reported by Shrock and Malott (1933, 351). The writer has found specimens since that time. The sand grains in this facies show the same general characteristics as do those in the lower part of the sequence, though they are usually less well rounded and frosted. Deformation has imposed a pseudo-cleavage on the rock; when struck with a hammer the sandstone separates into rhomboidal blocks bounded by thin zones of finely granulated quartz. At a second blow, the block disintegrates into angular grains of crushed quartz. The thickness of this facies is 10-15 feet, or even more for there has been considerable faulting within the sandstone. Where the bedding could be determined it was found to dip steeply toward the floor of the quarry. This finer grained, fossiliferous facies is provisionally correlated

with the Glenwood sandstone-shale sequence of Illinois and adjacent states (Plate 1, Column 1).

Within and adjacent to the sandstone are several fault blocks of dolomitic limestone. At the east end of the sandstone outcrop are a few feet of buff, oölitic dolomite similar to certain phases of the Shakopee and Oneota dolomites of Wisconsin. Near the west end of the sandstone, several small blocks of thin-bedded dolomitic limestone contain *Leperditia fabulites* and strophomenoids. Near the middle of the sandstone exposure, and separated from it by a curved fault plane dipping steeply to the northward, once lay a large fault block of dolomitic limestone. Before the strata were quarried away, the following section was measured, presumably in descending order from north to south across the northeastward-dipping beds:

SECTION OF STRATA EXPOSED IN A FAULT BLOCK ALONG THE MIDDLE OF THE SOUTH WALL OF THE McCRAY QUARRY

9. Dolomite; brown, even-bedded and granular, with a few chert nodules near the top ---------- 6′
8. Limestone, dolomitic; brown and somewhat argillaceous ---------- 3′
7. Shale; light gray, alternating with gray, argillaceous dolomitic limestone ---------- 3′
6. Limestone, dolomitic; brown to chocolate-colored, slightly granular and well-bedded in strata averaging about 6″ thick ---------- 3′
5. Limestone, dolomitic; light-buff, thin-bedded and finely crystalline ---------- 5′
4. Limestone, dolomitic; light-brown, granular and in one thick and one thin bed ---------- 3′
3. Limestone, argillaceous; light-buff, fine-grained, much fractured and weathered to a chalky condition ---------- 6′
2. Sandstone; similar to unit 1. This zone is apparently separated from unit 3 by a fault which is concealed under the quarry road ---------- 6′
1. Sandstone; white, quartzose, and so badly fractured that the bedding is obliterated. Estimated thickness ---------- 15′

Total ---------- 50′

Lack of fossils and distinctive lithological units make the age of this limestone sequence uncertain. It may immediately overlie the Glenwood facies of the sandstone, as Shrock and Malott suggested (1933, 352).

In the southwestern corner of the quarry, a westward-pitching syncline consists of several lithological units (Plate 3 and Fig. 4). On the east the fold fades into a broad fractured zone and on the north it terminates abruptly against a fault dipping steeply to the north. The following section, in descending order, was measured from west to east across the nearly vertical beds. The figures represent true thicknesses.

SECTION OF STRATA EXPOSED IN THE EXTREME SOUTHWESTERN CORNER OF THE McCRAY QUARRY, (DESCENDING ORDER)
(Column 6, Plate 1)

Division 6

10. Limestone, dolomitic: buff and somewhat mottled, fairly thin-bedded (4″-6″), "sandy"-weathering and much fractured. The strata are appar-

ently folded into a syncline which pitches steeply into the west wall of the quarry. Visible thickness is estimated at ----------10′

Division 5

9. Limestone, somewhat dolomitic: blue-gray, semi-lithographic to granular or dense, thin-bedded, fossiliferous rock, containing much clastic quartz (may be as much as 35%). Some of the sand is present in disconnected lenses; some in irregular stringers; and some is so disposed as to suggest the filled burrows of a burrowing organism. The beds are fairly thick (6″-36″) in the main, and the lower 5 feet are slightly argillaceous, somewhat thinner bedded and without much quartz except in the lower foot. There are numerous convex brachiopod shells in some layers, thin layers of comminuted shell matter in others, and a few white chert nodules (2″-4″ long) in the upper 3 feet ----------20′

Division 4.

8. Dolomite, sandstone and shale alternating: this zone comprises a series of beds of dark-gray, arenaceous dolomitic limestone, dark-gray arenaceous and calcareous shale, and gray sandstone, all in thin beds. There is an 8″ quartzitic layer about 1 foot from the top of the zone, and there are numerous thin limestone layers in the lower 4 feet. The sequence is much shattered and weathers irregularly so that the exposure has a ribbed appearance in the quarry wall ----------5′

7. Limestone, dolomitic and argillaceous: similar to rock below, but thin- (4″-12″) and irregular-bedded. The entire unit is much shattered by horizontal, closely spaced, southward-dipping fractures ----------3′

6. Limestone, dolomitic and argillaceous: buff-blue, fine-grained, fairly heavy-bedded (6″-30″), much fractured rock ----------8′

5. Limestone, dolomitic and argillaceous: light-buff, fine-grained, chalky rock with many horizontal, closely spaced, southward-dipping fractures which cause the rock to separate into post-like fragments normal to the planes. The rock is full of "shatter-cones." While only about 6 feet are certain, the nature of the float to the east strongly suggests that this unit may extend in that direction for 15-20 feet. It appears to end against a fault zone ----------6′

Total ----------52′

This section is partly duplicated at several other points in the northern half of the quarry. While no fossils were found in this succession, the distinctive arenaceous dolomite, underlaid by the alternating sandy shales and arenaceous and argillaceous limestone layers, is sufficient to identify it.

The east wall.—The strata exposed in the east wall of the quarry are so much broken by faults that it has been impossible to measure a continuous sequence of any thickness except in the northeast corner of the quarry. Near the south end of the east wall, and separated from the large mass of sandstone and oölitic dolomite by 30 to 40 feet of much fractured gray, dolomitic limestone, is a mass of dark-gray, calcareous shale (Plate 3 and Fig. 4). This shale mass appears to comprise a fault block which is separated from adjacent rocks by faults. Beneath are thick-bedded, gray, dolomitic limestones and pockets of gray sandstone which have been crushed and pushed into the shale, and to the north the shale ends against a much fractured, light-gray, dolomitic limestone with obscure bedding. Several thin (3″-4″)

layers of impure limestone near the south margin of the exposure, but clearly a part of the shale formation, stand in a vertical position, and along the northern margin similar layers dip steeply to the south, suggesting that the shale mass is a broken syncline pitching eastwardly into the quarry wall; a situation somewhat similar to that found almost due west across the quarry where the same shale formation appears again. Weathering, facilitated by the intensely fractured condition of the shale, has reduced it to a mass of small angular chips with the consequent destruction of all sedimentary features. Some parts of the shale mass resemble the so-called "pencil" shales of the Indiana and Illinois Pennsylvanian in the way the rock separates into small prisms. Diligent search failed to reveal a single fossil, hence the age of the formation is uncertain from this exposure. The thickness represented must be at least 15 feet and is probably more.

Near the middle of the east wall there is a small fault block which consists of nearly vertical, thin-bedded, dolomitic limestone containing an assemblage of fossils resembling those of the "Upper Buff" beds of Wisconsin. As is so often the case in the McCray quarry, this sequence of not over 8 or 10 feet is separated from adjacent strata by fracture zones, hence its stratigraphic associates are not clear. The fauna is listed above.

In the northeast corner and east of the corner to the edge of the glacial drift is a well exposed sequence of strata containing several diagnostic zones recognized elsewhere in the quarry. This section, given below in descending order, was measured from west to east across the strata which are steeply inclined to the west. The figures indicate true thicknesses.

SECTION OF STRATA EXPOSED IN THE NORTHEAST CORNER OF THE McCRAY QUARRY, (DESCENDING ORDER)
(Column 7, Plate 1)

Division 8

18–17. Limestone, dolomitic: brown, gray or white, semi-lithographic, thin-bedded (1″-4″), and with the thin strata separated by films of somewhat carbonaceous shale. Some of this shale is probably an original sediment, but certainly much of it is the result of intraformational solution. There are many small faults cutting across the bedding, but the displacement is always less than an inch or two. This zone is cut off to the west by a prominent fault plane which dips easterly at a very high angle and is marked by a zone of intense brecciation ---------- 18.5′

16–15. Limestone, dolomitic: gray, semi-lithographic, thin-bedded (1″-4″), with a few layers of finely granular rock. There are numerous strap-like markings or structures with elliptical cross-sections, which are somewhat lighter in color than the surrounding rock. These fucoidal structures, disposed mainly parallel to the bedding planes, give the rock a spotted appearance. They are especially numerous in the upper 4.5 feet though they are by no means limited to those beds. There are numerous stylolites along which are concentrated films of black, carbonaceous shale. Some of the stylolites appear to have localized small faults which cut across the bedding. Solution along some of the striated and slickensided columns of the stylolites has left films of shale similar to those separating many of the beds. The base of the sequence marked the steep east wall of the quarry in the summer of 1934 ---------- 13.5′

Division 7

14–13. Limestone, dolomitic: light-brown, fine-granular, fairly thin- (4″-10″) and irregular-bedded, sparsely fucoidal, and with the "bumpy" bedding planes separated by wavy films of black shale. Fossil stromatoporoids (*Cryptophragmus* and *Kentlandia* gen. nov.) are scattered throughout. The lower 6″ tend to be very thin-bedded ---------- 8.5′

12. Limestone, slightly dolomitic: dark-gray, crystalline and a veritable coquina of *Cryptophragmus antiquatus*, *Kentlandia imbricata* gen. and sp. nov., and *K. irregularis* sp. nov. ---------- 2.5′

Division 6

11. Limestone, highly dolomitic: buff, somewhat argillaceous, and in heavy beds (6″-2′). The rock is intensely fractured, and weathering reduces it to a "sandy" condition. The fresh rock is a gray, crystalline dolomitic limestone ---------- 6′

10. Limestone, dolomitic: light-brown to buff, argillaceous, fine-granular, heavy-bedded (4″-24″) rock similar to 11, but somewhat heavier bedded and containing a few chert nodules in the upper half ---------- 30′

Division 5

9. Limestone, somewhat dolomitic and highly arenaceous: brown to dark-gray, white to bluish-gray weathering, semi-lithographic or fine-granular, thin- to thick-bedded (2″-24″) and containing many irregular stringers, lenses and filled burrows of clastic quartz and many thin zones of comminuted shells. In the thicker sand lenses there are numerous small (0.5″-1″) limestone pebbles giving the layer a conglomeratic character. In some of the upper layers (toward the west) systems of ramifying fucoidal rods are present. On a deeply weathered surface these fucoidal stems appear lighter in color than the surrounding rock and give the bed a spotted appearance. When the dense matrix is removed from around them, these fucoids form a complex three-dimensional network of interlacing bars and stems. The heavier beds of the unit would undoubtedly break up into thinner layers under severe weathering. A few nodules of white chert are scattered through the upper 3 feet of the unit. The strata of this unit now form the east wall of the quarry for some distance south of the northeast corner, and comprise conspicuous roches moutonnées east of the wall, the eastern slopes of which disappear under the glacial drift ---------- 15′

Total ---------- 94′

The arenaceous, dolomitic limestone (Div. 5) and the stromatoporoid zone (Div. 7) are of special interest in this section, since both have been found elsewhere in the McCray quarry, and the latter has also been found in the Means and McKee quarries. In addition to the stromatoporoids, *Leperditia fabulites* and *Liospira* were collected from Div. 7.

The north wall.—One of the thickest sections found in the quarry is exposed along the north wall (Plate 3 and Fig. 3), but it is not continuous. Several almost vertical fault zones break the continuity of the succession and also are responsible for the intense fracturing exhibited by certain of the beds. The following section, which was measured and estimated from west to east, must, therefore, not be taken as a continuous one. Faulted and fractured zones will be indicated. All available evidence shows that the beds of the section are top side up (top to the west).

SECTION OF STRATA EXPOSED IN THE NORTH WALL, CHIEFLY EAST OF THE RAMP, OF THE McCRAY QUARRY, (DESCENDING ORDER)
(Column 4, Plate 1)

Division 8

19–17. Limestone, dolomitic: gray porous dolomitic layers alternating with thin beds (1″-4″) of bluish-gray, semi-lithographic, dolomitic limestone full of fucoids. There are many specimens of a narrow *Tetradium* in the lower 4.5′ of the sequence ---------- 23′

16. Limestone, somewhat dolomitic: gray, white-weathering, thin-bedded (1″-4″), fucoidal dolomite similar to the semi-lithographic beds in the sequence just described ---------- 4.5′

15. Limestone, somewhat dolomitic: similar to 16 except not so fucoidal and containing numerous small fossils on the upper surfaces of beds. This unit is terminated toward the east by a fault breccia ---------- 8′

Covered by ramp: Div. 7 probably is partly or entirely represented in this interval ---------- ?

Division 6

11–10. Limestone, dolomitic: gray-brown, fine-grained, dense or porous, mottled, fairly heavy-bedded (6″-24″), containing a few white chert nodules about 10 feet below the top. There are some fucoids along bedding planes, and in some layers there are numerous irregular openings which may represent weathered fossils. The rock is much fractured, with thin brecciated zones, though there is no evidence of displacement. The rock weathers to a mottled appearance on the surface. The top of this sequence forms the steeply inclined east wall of the ramp cut ---------- 36′

Division 5

9. Limestone, somewhat dolomitic: gray to bluish, semi-lithographic, fairly thin-bedded (2″-6″), with some mottled buff and gray layers. The buff parts are weak and somewhat argillaceous. Most layers contain much detrital quartz sand, concentrated in irregular stringers and lenses paralleling the bedding and cemented by calcareous material. Fossils are not common except in the lower 7 feet, in which thin-bedded, semi-lithographic limestones alternate with granular, dolomitic limestones. Argillaceous partings are numerous. This zone probably supplied the large "molluscan fauna" already mentioned.

Throughout the entire sequence are zones of drag-folding, and there are numerous small cross-faults, but no displacements exceed a few inches.. 21′

Division 4

8. Limestone, dolomitic: brown, granular rock which becomes argillaceous and arenaceous toward the base ---------- 5′

7–5. Sandstone, limestone and shale: a series of poorly cemented, calcareous-bound sandstone layers grading downward into a band of purer sand about 1 foot thick, which gives way to light-buff, arenaceous dolomitic shale and earthy, dolomitic limestone. The entire zone is much fractured and ends abruptly on the east against a vertical fault ---------- 22′

This section, no longer available because of quarrying, duplicates beds in the northeast and southwest corners of the quarry, and near the center of the quarry and the sump. The rich molluscan fauna of the north wall does not appear in any of these sections; faulting in the north wall may have placed the fossiliferous beds in their present position. Even if the molluscan

zone does not belong in unit 9 of Div. 5, it almost certainly lies either directly above or below the sequence of arenaceous limestones. This large molluscan fauna, which is clearly older than the stromatoporoid zone (Div. 7), will not be listed here, but it will be found in the discussion of Div. 5 and in the faunal table below.

In the northwest corner of the quarry, and along the west wall as far as the bedding could be distinguished, there was exposed in 1932-33 a thick section of thin-bedded and thick-bedded, dolomitic limestones, some of which showed numerous chert nodules. In this sequence were several prominent fractures and faults which are now known to represent considerable displacement in several instances (Fig. 5). Recent excavations, however, have removed

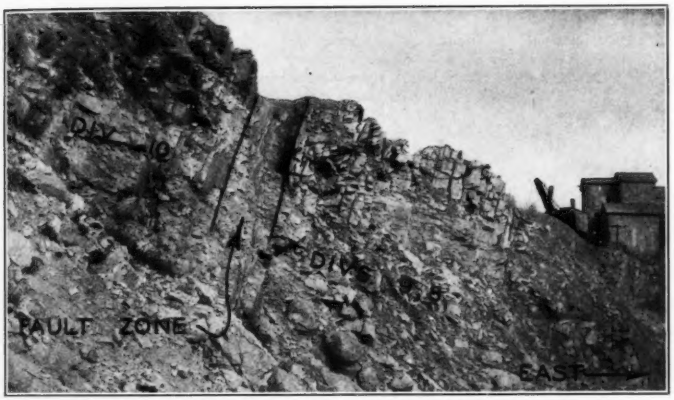


Fig. 5. View, looking northwest, in the northwestern corner of the McCray quarry. The westward-dipping strata of Div. 10 are separated from those of Divs. 9 and 8 by a fault zone which roughly parallels the bedding. The thin, brittle beds of Divs. 9 and 8 are much more fractured than the heavy beds of Div. 10. This photograph was taken in the summer of 1928, since when the strata in the immediate foreground have been removed.

most of this section. It is advisable to include this old section and fit it into the general stratigraphic column which has been constructed for the entire disturbed area. The section was measured from west to east, across the westward dipping strata, chiefly in the northwestern corner of the quarry.

Generalized Section of Strata Exposed in the Northwestern Corner of the McCray Quarry, (descending order)

(Column 5, Plate 1)

Division 10

28. Limestone, highly dolomitic: buff-gray, mottled, porous rock with uneven texture, in beds averaging 1 foot thick. The rock weathers to buff, dolomitic sand. There are a few scattered chert nodules. The lithology

strongly suggests the Galena of Wisconsin. Numerous silicified colonies of *Columnaria* were found ----------75'

Division 9

27–23. Limestone, dolomitic: brown to gray, uneven-textured, cherty rocks in beds approximately 8 inches thick. White and brown chert nodules are numerous along the bedding planes and within the heavy layers. A prominent fracture zone in the upper part of the unit may represent a bedding fault; it apparently does not affect the continuity of the succession. The lower part of the sequence is relatively even-textured, thinner-bedded, dense, and assumes the lithological character of the "glass-rock" of Wisconsin. Beds near the base contain *Columnaria halli*, *Tetradium* cf. *cellulosum*, *Hesperorthis tricenaria*, *Strophomena trentonensis*, *Ctenodonta gibberula*, and *Lyrodesma* cf. *acuminatum* ----------65'

Concealed by Faulting

Division 8

19–15. Limestone, dolomitic: gray, white-weathering, semi-lithographic, thin-bedded (2″-6″) rock without chert. It is characterized by an ostracod fauna, which also includes some other fossils (*Columnaria halli*, *Hesperorthis tricenaria*, *Rhynchotrema minnesotense*, *Zygospira recurvirostris*, *Cyrtodonta* cf. *huronensis*, *Bathyurus spiniger*, *Isotelus gigas*, *Leperditia fabulites*, *Leperditella sulcata* and *L. tumida*) ----------34'+

or —

Total ----------174'

At present a thick sequence, broken into several parts by faults, but continuous for the most part, is exposed in the central part of the quarry around the sump and in the adjacent west wall. This section, as determined in December, 1936, is given below. It was measured from west to east across the westward dipping strata. The figures indicate true thicknesses.

SECTION OF STRATA EXPOSED IN THE CENTRAL PART AND WEST WALL OF THE McCRAY QUARRY, (DESCENDING ORDER)
(Columns 2 and 3, Plate 1)

Division 10

28. Limestone, highly dolomitic: dark gray to buff, porous, even- to uneven-textured, fine-granular, heavy-bedded (6″-60″), horizontally streaked and banded, with a few scattered white chert nodules and numerous silicified colonies of *Columnaria*. A thin (4″) zone of silicified bryozoans lies about 14 feet above the base of the unit. The rock weathers to a buff, dolomitic sand and becomes somewhat thin-bedded in the upper part, where horizontal banding is best developed. This banding appears to be due largely to alternating thin layers of different texture, separated by films of black shale ----------75'

Division 9

27. Limestone, dolomitic: brownish-gray, semi-lithographic, fairly heavy-bedded (6″-24″), with numerous nodules of white and brown chert and an occasional silicified colony of *Columnaria*. The rock consists of a dense matrix surrounding irregular areas of coarse grained material ----14'

26. Limestone, slightly dolomitic: gray, white-weathering, lithographic, conchoidally-fracturing, lenticular-bedded rock in wedge-shaped beds averaging about 4″ thick. These lenticular beds are separated by black shale films and are much fractured. Differential movement of the contiguous beds has shattered this brittle unit, and has produced many small cross-faults ----------4'

25. Limestone, dolomitic: light-brown to gray, splotched or mottled, dense to coarse-grained rock containing many nodules of white or brown chert, lying between and within the fairly heavy (6″-24″) beds, and numerous silicified colonies of *Columnaria*. There are many thin (4″-12″) layers of fucoidal, blue, dolomitic limestone especially in the lower 10 feet, in which the rock is relatively dense and contains thin lenses of coarse-grained material. The lower part of the unit becomes splotched in horizontal bands on weathering, while the upper part takes on a light gray color ---------- 26′

24. Limestone, dolomitic: blue-gray, thin-laminated, intensely fucoidal rock in which the fucoids have the appearance of flattened cables. This zone is present in several sections in the northwestern corner of the McCray quarry, and contains orthoceratite cephalopods ---------- 1.5′

23. Limestone, dolomitic: cherty rock similar to unit 25 except somewhat thinner-bedded (2″-4″) ---------- 20′

22. Limestone, dolomitic: bluish-gray, lithographic, thin-bedded (1″-3″), separating readily along slightly undulatory surfaces which in transverse section are marked by wavy films of black shale. The rock breaks with conchoidal fracture into small blocks about 2 inches across. This unit is well exposed at several points in the northwestern part of the McCray quarry and also along the west wall south of the shale exposure ---------- 10′

21. Limestone, slightly dolomitic: light-gray, even-textured, fairly fine-grained rock in a single massive bed ---------- 6′

Total ---------- 156.5

(Interval concealed by talus or eliminated by faulting.)

Division 8

20–15. Limestone, dolomitic: a series of gray, dense and fine-granular, fairly thin-bedded (2″-4″) units containing numerous fucoids and having shale films separating the layers. Minute ostracods occur in beds and several orthoceratite cephalopods were found. Most of Div. 8 seems to be represented southwest of a fault zone at the pump which drains the sump ---- 45′

(An interval of faulted and fractured rocks in which the bedding is uncertain)

15. Limestone, dolomitic: gray, semi-lithographic, thin-bedded (1″-4″) rock containing numerous irregular masses of darker and somewhat coarser limestone. These bands and masses tend to be lenticular. Some drag folding is present in the shaley lower 18″. Upward this unit loses its bedded character in a fault zone ---------- 2.5′

Division 7

14c. Limestone, dolomitic: dark brown, lithographic bed with crystalline stringers ---------- 1′

14b. Limestone, dolomitic: light-gray, lithographic, thin-bedded (3″-8″), smooth and conchoidally fracturing rock characterized by numerous calcitic rods about 1 mm. across and crystalline stringers. The bedding planes are wavy, and the rock is considerably shattered ---------- 2.5′

14a. Limestone, dolomitic: dark gray, fine-crystalline to semi-lithographic with many small calcitic rods, layers of coarsely crystalline material, some of which are finely comminuted shells, and numerous colonies of *Cryptophragmus*. A 2″ bedding breccia, formed by slipping between the beds, lies 6 inches below the top ---------- 3.5′

13. Limestone, dolomitic: light-gray, lithographic, and very thin-bedded

(0.5″-1″) with the laminae separated by paper-thin films of greenish and black shale ---------- 0.5′

12. Limestone, somewhat dolomitic: dark-gray, medium to fine grained crystalline rock separated by wavy films of black, carbonaceous shale into irregular beds averaging a few inches thick. A veritable coquina of *Cryptophragmus* and *Kentlandia* gen. nov. ---------- 2.5′

Division 6

11. Limestone, dolomitic: buff-gray, finely granular, fairly heavy-bedded (2″-36″), with irregular separation planes marked by black, shalely films. The rock weathers to buff, granular dolomitic sand ---------- 6′

10. Limestone, dolomitic: light brown, splendent, finely granular, fairly heavy-bedded (4″-24″), weathering to buff, granular dolomitic sand. There are a few white chert nodules in a two-foot zone about 8 feet below the top of the unit. The upper 8 feet above the cherty zone consists of alternating bands of gray and buff dolomitic limestone about 1 foot thick. The buff layers are granular, the gray ones are dense. *Thaleops ovatus* noted ---------- 30′

Division 5

9. Limestone, dolomitic: gray to light brown, semi-lithographic, fairly heavy-bedded (4″-24″) rock with numerous lenses and stringers of clastic quartz. The upper part of this unit is exposed just east of the wall of the deepest excavation a few tens of yards northeast of the sump, but the lower part is covered by the crushed stone on the quarry floor ----- 5′

Total ---------- 53.5′

Many of the sections described above were measured previous to 1935. Since that time large segments of the walls have been blasted away and crushed, with the result that parts of some and all of other sections are destroyed. New excavations in the floor of the quarry have emphasized the fault-mosaic of the disturbed area. The stromatoporoid zone (Div. 7), well exposed in the northeast corner of the quarry before being blasted away, is now very well exposed at the sump and again to the northwest and southwest along the west wall. This zone probably is present in the north wall, under the track on the ramp, even though it was not seen.

The block in the north wall containing the rich molluscan fauna (presumably Div. 5 in large part) also has been blasted down, and it is now known that it was bounded on the north by an almost vertical fault. Every day of quarrying removes some strata and reveals new sections; remarks and conclusions are necessarily provisional and may require alteration. It has been with this in view that the attempt has been made to construct a generalized stratigraphic column for the Kentland quarries, making local correlations between fault blocks, estimating thicknesses of different units conservatively, and correlating Kentland zones with formations outside the state only when faunal and lithological similarities made such correlations obvious.

Conditions of Life, Death and Burial

Twenhofel (1931, 407-424) has shown that organisms living in any given environment may also die and be buried there; or, they may die and be buried in a different habitat or environment; or, they may die in a second

and be interred in a third. The character of the fossils themselves frequently shows something of their history before burial. The Kentland faunas, by virtue of their composition, condition of preserved parts, and character of those parts, furnish some evidence concerning their vicissitudes before entombment.

Division 5. Molluscan Zone

The lowest important fossiliferous horizon in the Kentland sequence is the "molluscan zone" comprising the lower 5-7 feet of Div. 5. The bluish-gray, dense, fairly thin-bedded dolomite is highly fossiliferous, and in some instances almost a coquina. Pelecypods and gastropods are the dominant fossils, though cephalopods are abundant. Brachiopods and the cranidia and pygidia of trilobites are common. Virtually all shells, valves and other skeletal parts are unbroken; pelecypod valves commonly are not even separated. The shells lie without discernible uniformity of orientation.

Almost all fossils of this zone are molds or fillings. They give no evidence of scavengers' action, nor do they indicate that the shells were shuffled by currents and waves. The unbroken condition of the shells, some of which were thin, as well as the lack of definite disposition or arrangement, strongly suggests that they were little disturbed after death. Evidently the organisms died where they lived, and were buried there soon after death.

Division 5. Arenaceous Limestone

Most of Div. 5 is thin-bedded limestone characterized by variable amounts of clastic quartz and abundant traces of current anad wave action. Quartz is wanting in some layers, but in others comprises as much as 45% of the rock. When released from its calcareous bondage, this sand exhibits excellent sorting (Fig. 2 and Plate 2, Fig. 6). Current and wave action appear to have produced this condition.

The fossils of Div. 5, except those in the molluscan zone at the base, are mainly the thin, concave or convex valves of strophomenoid brachiopods (*Rafinesquina*, etc.). These are almost always arranged parallel with the bedding and, in the case of the convex valves, with the convex side up (Plate 4, Fig. 6). This orientation of the shells is attributed to current and wave action and strengthens the conclusion that the bottom materials of Div. 5 were considerably stirred before final deposition. Many of the shells may have been brought to their final resting place from other habitats.

Division 7. Stromatoporoid Zone

This zone is composed of fairly well preserved colonies of stromatoporoids in a matrix of crystalline limestone. No other fossils are abundant. The abundance of individuals, state of preservation, and unbroken condition of many of the smaller colonies of *Cryptophragmus*, strongly suggest that the organisms lived, died and were entombed where they now occur. Apparently the colonies merely fell over into the mud on the bottom and were subsequently buried. The fragmented condition of many of the larger col-

onies indicates some disintegration. Furthermore, many of the slender colonies of *Kentlandia,* which certainly in life assumed a vertical position, are found prostrate.

Some trilobite fragments and ostracod shells are associated with the stromatoporoids. It is possible that the trilobites lived on the bottoms between the stromatoporoids, but the ostracods may have lived most of their lives far from the place of burial. The profusion of stromatoporoids in this zone proves that environmental conditions were especially favorable for these organisms.

Division 8. Zone of Small Forms

The bryozoan-brachiopod-ostracod layers of Div. 8 are characterized by assemblages of organisms, of which many are much smaller than the norms of the species. These fossils are especially abundant on the upper sides of the layers but often are not visible because of the argillaceous films which separate the layers. The layers themselves are composed largely of comminuted shell matter. Apparently the comminuted materials represent shells macerated by scavengers and fragmented by waves, whereas the well preserved fossils on the upper sides of the layers were saved by an influx of mud which buried them instantly.

Most well-preserved fossils are the slender, delicate colonies of *Tetradium cellulosum, Helopora, Escharopora* and *Rhinidictya,* the entire valves of small brachiopods such as *Hesperorthis* and *Zygospira,* together with the broken fragments of larger shells of such forms as *Rafinesquina,* or the valves of small ostracods as *Leperditella, Eurychilina* and *Krausella.* Large convex valves are conspicuously absent. For example, the thin, flat dorsal valves of *Hesperorthis tricenaria* are abundant, many of them well preserved, but only a few fragments of the larger, convex ventral valve have been found.

Broken zoaria of *Rhinidictya* and *Escharopora,* complete or broken valves of *Strophomena, Rafinesquina* and *Leperditia,* and dismembered and often broken parts of trilobite carapaces form coquinas on the surfaces of many of the thin limestone layers. Not until the argillaceous covering has been removed, however, do the smaller and better preserved forms become visible.

There seems to be good evidence that currents were active along the bottoms, because of the absence of large shell fragments, except thin brachiopod valves (all of which are the flatter valves) and fairly flat plates from trilobite carapaces. On some of the layers occur small, pit-like depressions filled with shell fragments washed into place and stacked together. They are very common in the Means quarry.

The bryozoans of Div. 8, and possibly some of the ostracods, probably lived at or near the locality where they were entombed. The ostracods, having small volume, low density and relatively large surface area might, however, drift far without suffering much damage. Most of the other remains, especially those which are much broken, probably were drifted to their final resting place from the site of death, and the latter may not have been the same as the

environment in which the organisms lived. In the case of some of the brachiopods and trilobites, it seems certain that the distance between the sites of death and burial were sufficiently great to allow considerable disintegration of skeletal parts. In transportation the shell or skeletal parts would be disintegrated and the detached fragments sorted by the currents in accordance with size, weight and convexity or flatness. Consequently, if this separating process continued long enough, the fragments strewn along the ocean bottom would be arranged according to the characters just mentioned. It is perhaps in such a process that one must look for an explanation of the assemblage of organic remains in Div. 8.

FAUNAL CHART OF THE KENTLAND QUARRIES

	BR	T	4	4–6	5	6	6–8	8	9	10
COELENTERATA										
Streptelasma profundum	X							M	M	
Columnaria halli	X	X						M	M	M
	X							M		
Tetradium cellulosum								Mc	M	
	X							Me		
Cryptophragmus antiquatus							M7			
							Mc7			
							Me7			
Kentlandia imbricata gen. et sp. nov.							M7			
							Me7			
Kentlandia irregularis sp. nov.							M7			
BRYOZOA										
Rhinidictya exigua	X							Me		
Rhinidictya mutabilis	X	X						Mc		
								Me		
Rhinidictya trentonensis	X							Me		
Escharopora angularis	X							Me		
Escharopora recta		X						MMe		
Escharopora subrecta	X							Me		
Helopora alternata	X							Me		
Helopora mucronata		X						Me		
Helopora spiniformis	X							Me		
Helopora pulchella sp. nov.								Me		
Nicholsonella pulchra	X				M					
BRACHIOPODA										
Crania setigera	X							Me		
Pholidops trentonensis minor		T		M						
Hesperorthis tricenaria	X							MMe	M	
Glyptorthis bellarugosa	X							M		
Valcourea deflecta	X			M			M			
Pionodema cf. *conradi*				M						
Leptaena charlottae	X							M		
Rafinesquina minnesotensis	X			M						
Rafinesquina minnesotensis inquassa	X							M		
Rafinesquina cf. *hermitagensis*								MMe		
Strophomena plattinensis	X			M						
Strophomena plattinensis crassa var. nov.	X									
Strophomena auburnensis	X						M			
Strophomena auburnensis										

	BR	T	4	4–6	5	6	6–8	8	9	10
impressa var. nov.	X									
Strophomena trentonensis	X							M	M	
Rhynchotrema minnesotense	X			M			Me7	M		
Zygospira recurvirostris	X	X						M Mc Me		
Zygospira saffordi	X			M						
MOLLUSCA (Pelecypoda)										
Ctenodonta gibberula	X						M		M	
Ctenodonta cf. *levata*	X			M			M			
Ctenodonta cf. *logani*	X			M						
Ctenodonta ovata robusta	X					M				
Ctenodonta socialis	X			M						
Ctenodonta nasuta	X			M						
Cyrtodonta billingsi	X			M						
Cyrtodonta cf. *huronensis*	X			M				M		
Vanuxemia rotundata	X			M						
Vanuxemia decipiens kentlandensis var. nov.				M						
Vanuxemia sulcata sp. nov.				M						
Clionychia triangularis sp. nov.				M						
Lyrodesma cf. *acuminatum*	X								M	
MOLLUSCA (Gastropoda)										
Tetranota wisconsinensis	X			M						
Salpingostoma buelli	X			M						
Phragmolites grandis	X			M						
Raphistomina cf. *modesta*	X			M						
Omospira cf. *alexandra*	X					M				
Lophospira conradana	X			M						
Lophospira oweni kentlandensis var. nov.				M						
Lophospira perangulata	X			M						
Lophospira serrulata	X			M				M		
Lophospira sexlineata sp. nov.				M						
Liospira progne	X	X		M						
Liospira obtusa	X			M						
Liospira vitruvia	X	X		M						
Eotomaria trochoides sp. nov.	X			M						
Clathrospira subconica	X	X		M						
Hormotoma gracilis angustata	X			M						
Ophiletina sublaxa	X						M			
Eccyliopterus sp. nov., aff. *beloitensis*				M						
Eccyliomphalus undulatus	X			M						
Trochonema cf. *umbilicatum*	X	X					M			
Holopea ampla	X			M						
Stenotheca kentlandensis sp. nov.				M						
Hyolithes baconi	X			M			M			
Salterella billingsi	X			M						
Pterotheca expansa	X			M						
Pterotheca intermedia sp. nov.				M			M			
Pterotheca cf. *attenuata*							M			
MOLLUSCA (Cephalopoda)										
"*Orthoceras*" cf. *sociale*				M						
Spyroceras cylindratum	X	X					M			
Kionoceras kentlandense	X			M?			M?			

	BR	T	4	4-6	5	6	6-8	8	9	10
Actinoceras beloitense				M?			M?			
Whitfieldoceras mumiaforme	X			M						
Poterioceras kentlandense								Mc		
Kentlandoceras shrocki	X			M						
Tripteroceras indianense sp. nov.				M						
ARTHROPODA (Trilobita)										
Bathyurus spiniger	X							M		
Isotelus gigas	X	X		M			M	Me		
Bumastus milleri	X						Me?			
Thaleops ovatus	X			M		M				
Ceraurus bispinosus	X			M						
Ceraurus dentatus		X					M	M Me		
Ceraurus pleurexanthemus	X	X		M			M			
Calyptaulax cf. *eboraceus*								Me		
ARTHROPODA (Ostracoda)										
Leperditia fabulites	X		M		M		M	{MMe {Mc	M	M
Leperditella persimilis	X							McMe		
Leperditella sulcata	X							MMe		
Leperditella tumida	X							MMe		
Eurychilina subradiata	X	X						Me		
Eurychilina ventrosa		X						MMe		
Drepanella bigeneris	X							M		
Drepanella crassinoda	X							MMe		
Krausella arcuata	X							Me		

M—McCray quarry. Mc—McKee quarry. Me—Means quarry.
4—Division 4. BR—Black River. T—Trenton.

Nature of the Kentland Structure

Regional relations.—The Kentland complex lies on the southwestern flank of the Chicago branch of the Cincinnati geanticline, at the head of a broad syncline opening southward into the Indiana-Illinois coal basin (Fig. 6). Neither of Logan's (1931, 21, 22) most recent structural maps, of which one is based on the top of the "Trenton" and the other on the top of the St. Peter, shows any marked irregularity in the Kentland vicinity. Furthermore, Lamar's (1928, Plate 3) structural map of Illinois, based on the top of the St. Peter, shows no abnormal structural conditions in eastern Illinois, just west of Kentland. While it is possible that the data used in the maps just mentioned were so scattered as to fail to reveal the subsurface structure completely, it does not seem likely that they would have failed to reveal a deformation of the intensity of the Kentland area if this were large. All available evidence suggests that the disturbed area is small.

Geologically the strata in the 3 quarries comprise an Ordovician inlier surrounded by Devonian, Mississippian and possibly Pennsylvanian formations (Fig. 7). Devonian black shale and limestone have been reported from west, north and east of the quarry district, and Mississippian shales and limestones are known to be present a few miles east and southeast of the district, but of the occurrence of coal-bearing strata immediately south of the quarries in northern Benton Couny there is considerable doubt. Ashley (1898, 182-192), after carefully considering all available well data from the

Kentland vicinity, much of which was published earlier by Collett (1883, 52-60) and Gorby (1886, 206-219), concluded that there was some question as to the reliability of the information. He stated (p. 190ff): "In this section [25]. . . . occurs one of the most disturbed areas known in the State. . . . As to whether this disturbed structure extends into the coal basin just south cannot be stated. I am inclined to think it may to some extent, but not so as to materially effect the presence of the coal there. . . . Except at the outcrops as noted, all the data were obtained by the use of the self-pumping tubular drill. The thickness of the coals [which had been reported previously in the 'Schluttenhofen' basin] is judged by the distance the drill works between the

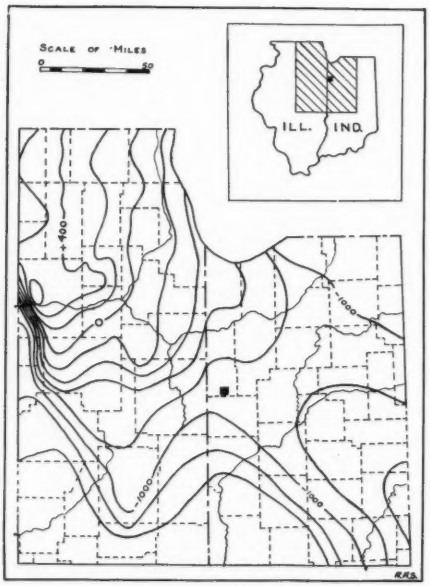


Fig. 6. Structure map of the top of the St. Peter sandstone in northwestern Indiana and northeastern Illinois; contour interval 200 feet. The Kentland area is indicated by the small black square. After Logan (1931), and Lamar (1928). Courtesy of the *Journal of Geology*.

waters first becoming black and its clearing up again. In the main coal field no reliance would be put upon data obtained in this way. . . . Until a test shaft has been sunk, or a core or other drilling made by parties whose knowledge and experience in the coal field make any report by them on the coal strictly reliable, we shall consider the question of workable coal in this area an open one. . . . there is a possibility that coals of coal measure age have

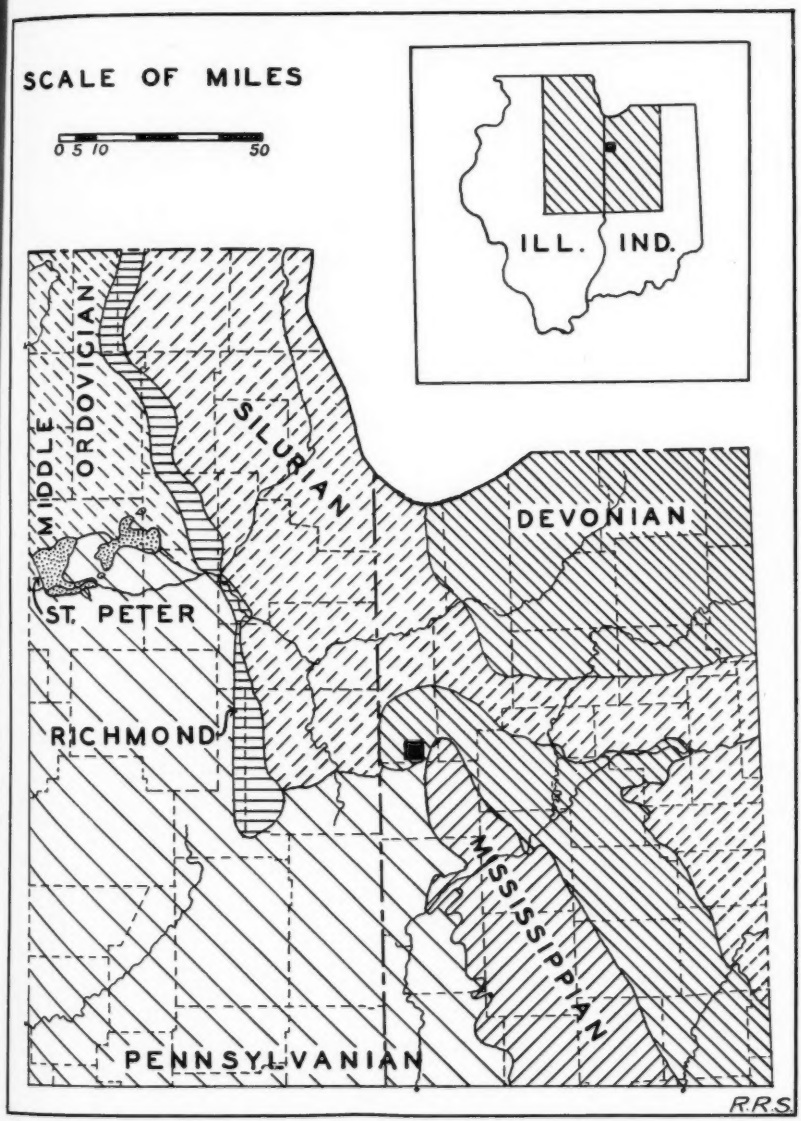


Fig. 7. Geologic map of a part of northwestern Indiana and northeastern Illinois, showing the geologic setting of the Kentland area, indicated by the black square. Modified after maps of Illinois by De Wolf (1917) and of Indiana by Logan (1932). Courtesy of the *Journal of Geology*.

been deposited here in an old channel or depression of some kind in the older rocks."

No recent well data have been forthcoming from the district immediately south of the quarries, so that little can be added to Ashley's conclusions. It seems possible, however, that early drillers mistook Devonian black shale for coal.

Size of the Disturbed Area.—The known Ordovician exposures and their attitude are shown in Fig. 1. They lie within an area less than one-half square mile in extent. Shrock and Malott (1933, 363), after examining data on the subsurface structure of the top of the "Trenton," concluded that ". . . . the Trenton, at short distances in all directions from the quarry district, appears to lie in its normal position on the southwest flank of the Cincinnati geanticline. This suggests that the disturbed area is small and of local extent rather than of regional extent." They concluded further, after examining all available data on surrounding geological formations, that (1933, 364) ". . . . the evidence suggests that the disturbed area is small, especially if the inlier formed by the upstanding mass [of Ordovician rocks] represents

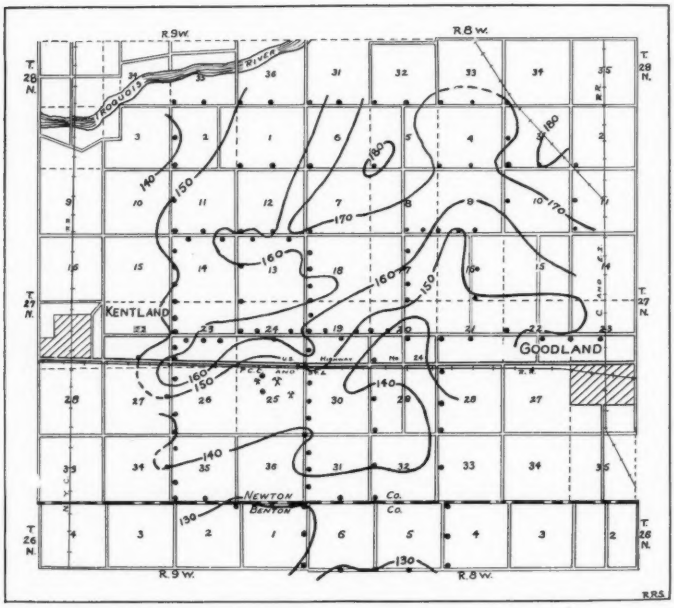


Fig. 8. Variation in magnetic intensity in the vicinity of Kentland, Newton County, Indiana; isomagnetic lines 10° apart. Large dots show where readings were made. Survey conducted by Dr. J. Zinn, July 16 and 17, 1932. Courtesy of the *Journal of Geology*.

most or all of it. The possibility remains, however, that part of the deformed rocks may have been covered by younger sediments. This of course presupposes that the disturbance antedated the deposition of the younger sediments."

Magnitude of Uplift.—The most recent information places the thickness of the so-called "Trenton" of the Kentland vicinity at about 450 feet. Logan's (1922a, 950) well record at Kentland shows the top of the "Trenton" at a depth of 1,060 feet and at an elevation of 379 feet below sea level. From these figures (1,060 + 450 = 1,510 feet) it is apparent that most if not all of the mass exposed in the present quarries has been uplifted at least 1,500 feet, and if the thickness of the Glenwood and St. Peter were to be added, the figure would be further increased.

Magnetics of the Area.—The area immediately surrounding the quarry district was surveyed with a Hotchkiss superdip and the results reported by Shrock and Malott (1933, pp. 366-368) in 1933. The data obtained by Dr. J. Zinn, who did the work, are indicated on Fig. 8. Their possible significance, however, must remain uncertain until much more extensive investigations are conducted.

Detailed Structural Features

Throughout the disturbed area there is ample evidence that the rocks failed chiefly through fracture, rarely by folding. As a result of the fracturing there are numerous interesting structural features which will be described in order to give a more complete picture of the nature of the structural complex.

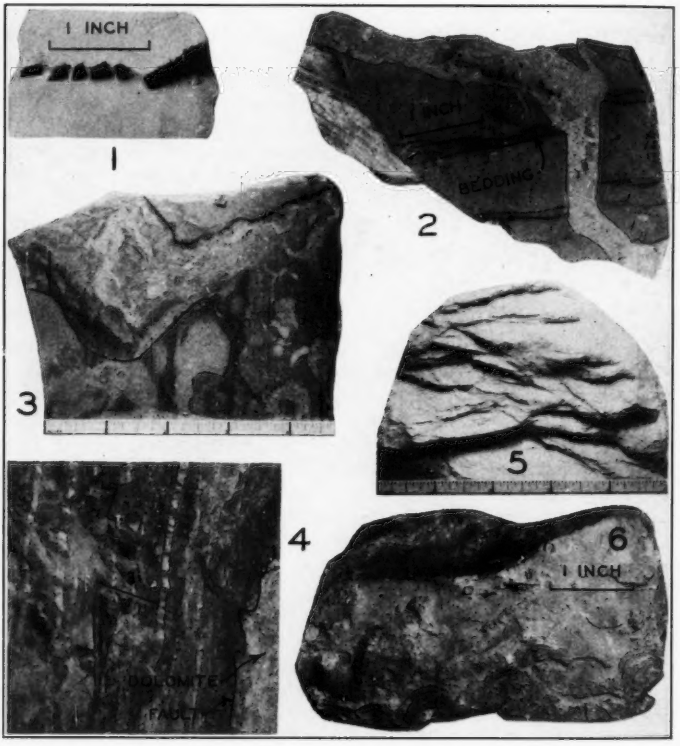
Faults.—Since the strata exposed in the quarries have been uplifted vertically some 1,500 feet, it seems fairly certain that the disturbed area must be outlined by essentially vertical or very steeply inclined fault zones, which separate the disturbed rocks from the relatively undisturbed strata surrounding. This fault zone is probably not a single continuous surface, but more likely a series of slice faults which, if seen in transverse section, would be arranged in echelon.

Several curved, steeply inclined fault surfaces appear in the McCray quarry (Plate 3); there has been intense fragmentation and considerable movement along them. Beds as much as 150 to 200 feet apart stratigraphically are found in juxtaposition, separated by a deeply grooved zone of intensely brecciated rock. In the southwestern corner of the McCray quarry the writer recently measured mullion structure along one of these surfaces in which the grooves were more than 2.5 feet wide and slightly over 4 inches deep. Such fault zones as the one just described may well be parts of the great bounding faults mentioned above.

In addition to the curved faults, there are many vertical or steeply inclined rectilinear fault zones along which considerable brecciation and movement have taken place. Some of the more conspicuous ones are shown on Plate 3. There are also several prominent bedding faults in the McCray quarry The eastern wall of the quarry once showed a steeply inclined, eastward-dipping fault which trended approximately north-south and almost parallel with the

strike of the westward-dipping beds. Similar faults are found along the north wall and in the southwestern part of the same quarry. The duplication of beds along the northern wall of the McCray quarry is believed to be due

PLATE 4



1. Small block of brittle, lithographic limestone from Div. 9(22), McCray quarry, showing a minute zigzag fault. The fault plane is "healed" within the rock mass through recrystallization. 2. Specimen from Div. 9(23), McCray quarry, showing a brecciated zone cutting across the bedding; its sides are slickensided, as is shown in the upper left part of the specimen. 3. Dragfold in a bed from Div. 5, north wall of McCray quarry. The fold is almost faulted across. 4. Exposure of Div. 11 (Shale) along the west side of the McCray quarry, showing fault contact with the adjacent dolomite of Div. 10. Note the thin bands of limestone in the shale. 5. Specimen of fractured sandstone from Div. 2. 6. Part of a layer from Div. 5(9), showing numerous convex brachiopod valves in the lower part of the layer. Most of these valves are arranged with the convex side up.

to movement along one of these steeply inclined faults, or along a series of small faults which in aggregate produce the same result.

Fracture patterns, Shatter-cones and Breccias.—All exposed rocks have been shattered by the deformation. The brittle limestones, especially the lithographic beds, have been much fractured and in some instances the displacement is a series of minute step-faults (Plate 4, Fig. 1). In such instances the actual movement does not much exceed an inch. In the tougher and less brittle rocks the fractures are more closely spaced and the weathered stone presents a surface broken into thousands of minute polygons outlined by innumerable tiny cracks. As a rule the actual fault plane has been "healed" within the beds by recrystallizatioon so that it is no longer visible and may not be apparent even when the rock is broken (See Plate 4, Fig. 1).

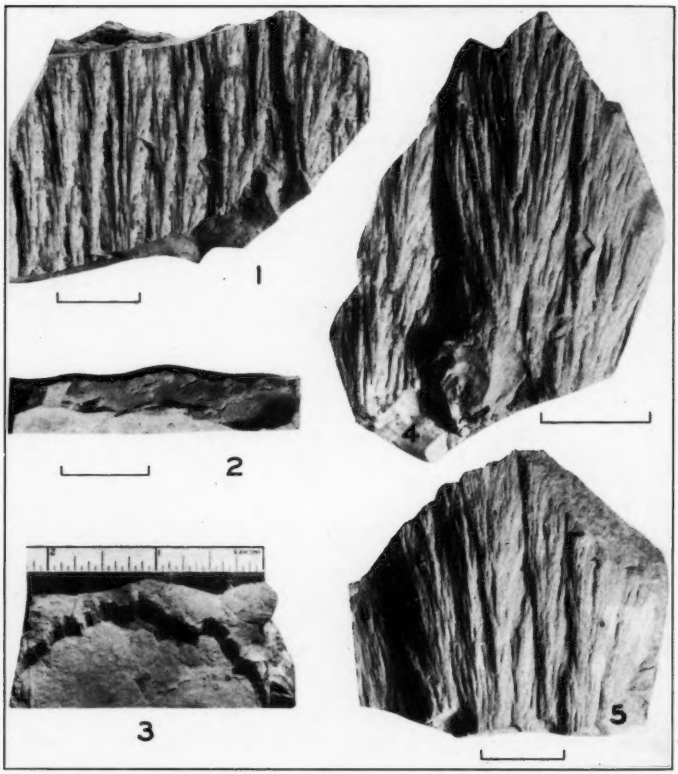
In several instances, systems of cracks or fractures, possibly representing fracture cleavage, were noted, and in each case there was an indication that the lower beds had moved up with respect to the overlying beds—a situation exactly opposite that found in folds formed by compressive or rotational stresses, but what should be expected if there was a vertical push from below. Dragfolds in the north wall of the McCray quarry, where the strata dip steeply to the west, show this same type of movement, and duplication of beds there seems to indicate that similar movement took place along a steeply dipping fault plane. This type of movement strongly suggests that the deformation may have been in the nature of a vertically directed upheaval in which some powerful force acting from below, first domed a great thickness of strata and then forced the dome upward, with faulting around the periphery and with the under beds of the sequence sliding upward against the overlying strata as great tension cracks opened at the top.

Specimens from the shale show a very intricate system of fractures which divide the surface of the mass into numerous polygonal areas, each tilted somewhat with respect to the surrounding areas, so that the surface has the appearance of a blunt-toothed rasp. A light tap from a hammer causes the rock to separate into small polyhedra which almost immediately disintegrate into irregular chips. There is also some indication of fracture cleavage in the more argillaceous beds between the dense limestone layers, but the fractures are too confused to show much concerning differential movement between the beds.

The sandstone of Divs. 2 and 3 has been so intensely sheared that there are few large masses in which constituent grains are not fractured. The originally rounded and frosted quartz grains have been abraded to some extent, and have in some instances lost the matte surface. There is also granulated quartz between the grains, and a microscopic examination of the heavy accessories shows numerous tiny euhedral crystals which are probably inclusions released from large quartz and other grains when the latter were cracked open. Only in the arenaceous limestone have the grains of quartz escaped most of the destroying influences just described, and even these grains suffered fracture (Plate 2, Fig. 4); when removed from the calcareous matrix they fall apart. The calcite of the matrix apparently recrystallized around the fractured grains.

One of the most interesting structural features in the quarries is the so-called shatter-cone. This consists of a semi-conical surface grooved in such a way as to appear to be composed of a series of overlapping or imbricating half cones (Plate 5). These shatter-cones may occur singly or in series, in the latter case forming curved surfaces which in transverse section have a scalloped appearance. The surface of the shatter-cone is a fault surface, (Plate 5, Fig. 3), but the displacement along the surface is usually less than

PLATE 5



1. Part of the surface of a "shatter-cone" showing the grooved surface and the parallel arrangement of the half cones. 2. Vertical view of 1 showing on the upper part of the figure a transverse section of the grooved surface. 3. Specimen showing the usual slight displacement between adjacent "shatter-cones." 4 and 5. Specimens showing the nature of the grooved surface of a "shatter-cone." All specimens are from Div. 8, McCray quarry. The scale in each figure except 3 represents 1 inch.

an inch. It is significant that the cones are variously oriented and show no definite relation to the bedding.

The great curved fault surfaces in the McCray quarry have essentially the same characteristics as the small shatter-cones and are believed to have been formed in the same way by the same forces. It appears that these unique structures are the result of some violent shock to which the rocks were subjected during the deformation, and it is significant that they characterize the so-called "cryptovolcanic" and closely related structures.

In many parts of the quarry, irregular stringers of brecciated material cut across the beds and joints (Plate 4, Fig. 2). These brecciated zones are usually less than an inch wide and are bounded by slickensided surfaces. They consist of angular fragments of limestone in a firm matrix of very fine-grained, bluish-gray or gray limestone. There is some suggestion that these zones are tensional features, for many of the fragments appear to have spalled from the adjacent walls. Some, however, are different from the wall rock and were introduced, as the fine-grained matrix is thought to have been. The "foreign" fragments are usually as angular as those from the wall rock. Wilson and Born (1936, 820-821) have described two types of breccia—"shatter breccia" and "injected powder breccia"—from the Flynn Creek disturbance in Tennessee, and these appear to have been formed by an explosive shock. Breccias at Kentland have the same characteristics as those found in Tennessee and may well have been formed in a similar manner.

In addition to the many small brecciated zones, there are several wide zones of brecciation associated with faults in the McCray quarry. These are several feet to several tens of feet across and are composed of large blocks of rock which lie as much as 200 feet apart stratigraphically. The rocks have been crushed together into a jumbled mass and then cemented by finer material. This type of breccia commonly shows considerable porosity and numerous open spaces. All evidence points towards large displacement along these broader brecciated zones.

Folds.—Folds are rare in the disturbed area and are closely associated with major fault zones. In the southwestern corner of the McCray quarry, the beds appear to be folded into a westward-pitching syncline which is terminated at the north by a fault zone (Plate 3), and at several points along the western wall, flexures are closely associated with dragging along prominent fault zones. The two shale masses appear to be small, steeply pitching synclines bounded by faults. The closely folded shale zone in the south wall shows that there was movement within the sandstone mass of which it is a part, even if the latter did not fold. The numerous dragfolds in limestone beds, such as the one in Plate 4, Fig. 3, show that some strata first yielded by folding and later broke along the axis of the fold with resultant faulting. In most of these cases the movement was that in which the under bed moved upward with respect to the overlying.

Nature of Deformation

Most of the structural evidence suggests strongly that the deformation was produced by some great force which, acting from below (perhaps with

explosive violence), first domed the rocks, then pushed them upward causing the domed mass to break from the surrounding strata along steeply inclined fault planes. During the upheaval, those blocks nearest the center of the disturbance moved upward rapidly, and produced reverse dragfolds and fracture cleavage. During this disturbance the rocks were intensely crushed and shattered, possibly because of the explosive nature of the forces, and extensive tension cracks appear to have formed. The brecciation observed in the McCray quarry is due to several causes. The thinner zones are associated with tension cracks, whereas the broad zones are related to large faults.

It seems certain that the jumbled mass which was left when the deforming stresses had finally relaxed was due chiefly to the forces associated with the uplift, but after the vertically directed forces were spent, the relaxation which set in probably caused some readjustment among the jumbled blocks and was responsible for some of the fracturing.

Probable Origin

To propose an hypothesis for the deformation of the rocks at Kentland, the following visible and inferred conditions must be considered:

A. A sequence of over 350 feet of limestones, sandstones and shales of Ordovician age have been uplifted vertically some 1,500 feet.

B. The disturbed area, known to cover less than one-half a square mile, but probably somewhat larger, is a fault mosaic in which blocks are tilted in every way.

C. The rocks have been intensely shattered; numerous fracture phenomena suggest that the deforming stresses must have affected the rocks with explosive violence.

D. Most of the structural evidence suggests an upward push, in which there was a vertical movement of a large mass of material within which adjacent parts were moving differentially and with the under beds moving upward relatively to the overlying.

E. Curved fault planes, always dipping steeply and sculptured with mullion structure, are common in the McCray quarry.

F. Shatter-cones are abundant and appear to be shear-cones resulting from some great shock to which the rocks were subjected.

G. Folding is uncommon and is always associated with fault zones. Small dragfolds are common and suggest, as do some of the fractures, that the under beds moved upward with respect to the overlying strata.

The following hypotheses may be considered:

1. Transportation of the entire mass by Pleistocene glaciers.
2. Regional folding or faulting.
3. Vertical uplift of a segment of the Pre-Cambrian basement and consequent deformation.
4. Igneous intrusion of a basic plug which did not closely approach the surface.
5. An explosion crater formed by the impact of a large meteorite.
6. An explosion of gases which had collected in petroliferous strata at a depth of 1,000 to 1,200 feet.
7. A deep-seated explosion, somehow related to an invading magma, raising the rock column over a quarter of a mile, intensely shattering the rocks, but leaving no indication of the passage of gases.

1. The most casual examination of the jumbled rocks, which are so intensely shattered, the large size of the mass, and the age of the strata all combine to eliminate glacial action as a possible explanation of the present position and condition of the rocks. Furthermore, the roches moutonnées and the grooved and striated surfaces at the McCray quarry show that the ice moved over the pre-glacial rock mound.

2. It seems highly improbable that any large fold or fault of regional extent is present in the Kentland area, because of the apparently localized nature of the disturbance (though it may be larger than appears from known exposures) and the fact that in the numerous wells in this part of Indiana there is no evidence of disturbance of the "Trenton" rocks other than that associated with the normal regional dip of the southwest flank of the Cincinnati geanticline.

3. It is possible that deformation was produced by the uplift of a block of the pre-Cambrian basement, outlined by preexisting faults, with enough fracturing to produce the fault mosaic which can now be seen. It would be difficult, however, to explain how simple uplift could produce the intense shattering of the sandstone and the widespread fracturing of the limestone, if this hypothesis were accepted. Furthermore, most of the structural features suggest doming of the strata, rather than simple vertical uplift with the development of a series of steeply dipping faults converging downward to form an inverted cone.

4. A basic plug may have intruded the basal part of the stratigraphic column at Kentland and caused the deformation of the overlying rocks, but in addition to the objections offered in 3, there is no apparent evidence, such as hydothermal action or mineralization, to indicate volcanic activity in the region. The possibility of explosion associated with deep-seated volcanic activity will be discussed under 7.

5. Boon and Albritton (1936) recently suggested that some of the so-called "cryptovolcanic" structures represent areas where the rocks had been disturbed by the impact of a meteorite; they pointed out that after a large meteorite strikes, the suddenly compressed rocks will expaand with explosive violence and the consequent disruption will shatter them.

The present author is inclined to rule out the possibility of a meteoritic impact, as an explanation for the Kentland complex, because of the lack of any evidence of a meteorite, the magnitude of the uplift, the thickness of strata affected, and the absence of any suggestion of heat associated with a body large enough to produce the stresses which must have been involved.

6. Since some of the strata now exposed in the quarries at Kentland are known to be oil- and gas-producing in other parts of Indiana, could gases, accumulated at a depth of 1,000 to 1,200 feet, suddenly have exploded and shattered the overlying rocks to the surface? In favor of such an hypothesis is the fact that there is considerable carbonaceous material in and between the layers at Kentland and not all of it appears to have come from intraformational solution. Almost insurmountable difficulties are encountered, however,

when one attempts to account for the intense shattering of the sandstones and the magnitude of the uplift. Furthermore, such an explanation would not account for the fact that strata a considerable distance below the oil-bearing horizon ("Trenton") have been involved in the disturbance.

7. A group of unique structures, recently described and designated "cryptovolcanic" by Bucher (1928, 1935, etc.), Wilson and Born (1936) and Boon and Albritton (1936) possess many features which are well displayed in the Kentland quarries. Bucher (1935, 20) listed the following characteristics for these structures:

1. They show a tendency toward a circular outline.
2. A central uplift is surrounded by a ring-shaped depression, with or without well-developed marginal folds beyond it.
3. In the larger disturbances the area of the uplifted central part is small compared to the areas that sank.
4. Where the nature of the rock materials permits any judgment, evidence is found of violent action, such as seems explicable only as the result of sudden release of pressure—that is, of an explosive force.
5. Except in the Decaturville structure, no volcanic materials or signs of thermal action have been observed.

The areal data on the Kentland complex are too meager to allow a definite statement as to its shape or size. All the present openings show rocks which have been uplifted to the same elevation and there is no indication that the area is surrounded by a ring-shaped depression, although the reported occurrence of "coal" in a number of wells several miles south of the quarry district may be suggestive. The shattered rocks indicate that the deforming stresses were probably created by the sudden release of pent-up forces, perhaps by explosion. The absence of volcanic materials and evidence of thermal action accord well with 5.

Bucher (1935, 20-21) concluded that:

> The evidence of explosive action in the center of these structures is sufficiently convincing to exclude the possibilitites of a nonvolcanic origin. . . . Violent explosions are usually regarded as phenomena characteristic of the last stages of volcanism. . . . But similar effects are to be expected where ascending columns of lava failed to break through to the surface. If in such circumstances the magmas are highly charged with gases, especially with water vapor, the gases may dissipate through joints and other fractures. Occasionally, however, such an escape may be prevented by the texture of the rocks, and the gases may accumulate near the surface. Then the pressure will rise to the point where it lifts the overlying rock columns. Mere lifting will allow the gas to escape, chiefly through fractures in the center, causing the characteristic disruption and jumbling of blocks and the upward movement recorded in cryptovolcanic structures . . . . It appears, then, that the cryptovolcanic structures here described form part of a natural series of disturbances which mark the beginning or the attempted beginning of volcanism in a region. . . .

If the Kentland complex is of cryptovolcanic origin, it would be classified under Bucher's "Disturbances produced by the explosive release of gases under high tension, without the extrusion of any original magmatic material, at

points where there had previously been no volcanic activity ('abortive volcanism'). . . ."

The writer is inclined to accept the cryptovolcanic origin of the Kentland complex because it seems the most reasonable hypothesis that can be formulated on the basis of available evidence.

Summary

This report describes a small area of greatly disturbed Ordovician rocks located about 3 miles east of Kentland, in northwestern Indiana. In the area, which is less than one-half a square mile in extent, 3 quarries reveal a 350-foot sequence of dolomitic limestones, sandstones and shales ranging in age from Prairie du Chien to Utica? or Richmond? Over 100 species of fossils are reported from 3 faunal horizons of Black River age. The Rocks in the area are intensely fractured and dip steeply in numerous directions, and the jumbled fault blocks comprise an intricate fault mosaic. The uplift and consequent disruption of the strata are thought to have been produced by a violent explosion which was related to cryptovulcanism in some past geological period. The extensive glacial drift mantle conceals the rocks surrounding the disturbed area and makes it impossible to determine the time of the disruption.

BIBLIOGRAPHY

ASHLEY, G. H. 1899—The coal deposits of Indiana. Ind. Dept. Geol. and Nat. Res., **23**d Ann. Rept.:1-1428 [184-191].

BASSLER, R. S. 1915—Bibliographic Index of American Ordovician and Silurian Fossils. U. S. Nat. Mus. Bull. **92** (2 vols.).

— —1932—The stratigraphy of the Central Basin of Tennessee. Tenn. Dep. Ed., Div. Geol.; Bull. **38**:268 pp.

———1935—Descriptions of Paleozoic fossils from the Central Basin of Tennessee. Jour. Washington Acad. Sci. **25**:403-409.

BLATCHLEY, W. S. 1904—Geological Map of Indiana.

BOON, J. D. AND C. C. ALBRITTON, JR. 1936—Meteorite craters and their possible relationship to "cryptovolcanic structures." Field and Laboratory **5**:1-9.

BUCHER, W. H. 1928—Cryptovolcanic regions. Jour. Washington Acad. Sci. **18**: 521-524.

———1935—Cryptovolcanic structures in the United States. Rept. XVI. Int. Geol. Congress (Washington), 1933, **2**:1055-1084 (Preprinted and issued in December, 1935).

BUTTS, CHARLES. 1926—Geology of Alabama (The Paleozoic Rocks). Geol. Surv. Ala. Spec. Rept. **14**:41-234, plates 3-76.

CHAMBERLIN, R. T. 1923—On the crustal shortening of the Colorado Rockies. Amer. Jour. Sci. (5) **6**:215-221.

COLLETT, J. 1883—Geological survey of Newton County. Ind. Dept. Geol. and Nat. Hist., **12**th Ann. Rept. :48-64.

CUMINGS, E. R. 1922—Nomenclature and description of the geological formations of Indiana. Handbook of Indiana Geology Pt. **4**:403-570.

CUMINGS, E. R. AND R. R. SHROCK. 1927—The Silurian coral reefs of northern Indiana and their associated strata. Proc. Ind. Acad. Sci. **36**:71-85.

———1928—Niagaran coral reefs of Indiana and adjacent states and their stratigraphic relations. Bull. Geol. Soc. Amer. **39**:579-619.

———1928a—The geology of the Silurian rocks of northern Indiana. Conserv. Comm. (Indiana), Div. Geol., Pub. **75**:1-226.

FOERSTE, A. F. 1921—Notes on Arctic Ordovician and Silurian cephalopods. Denison Univ. Bull., Jour. Sci. Lab. **19**:247-306; 1 fig., 9 plates.

———1932—Black River and other cephalopods from Minnesota, Wisconsin, Michigan and Ontario. Pt. I. Denison Univ. Bull., Jour. Sci. Lab. **27**:47-136; plates 7-37.

———1933—Black River and other cephalopods from Minnesota, Wisconsin, Michigan and Ontario. Pt. II. Denison Univ. Bull., Jour. Sci. Lab. **28**:1-146.

GORBY, S. S. 1886—Geology of Benton County. Ind. Dept. Geol. and Nat. Hist., **15**th Ann. Rept. :198-220.

———1886a—The Wabash Arch. Ind. Dept. Geol. and Nat. Hist., **15**th Ann. Rept. :228-241.

———1892—Geological Map of Indiana. (Included in **17**th Ann. Rept. Ind. Dept. Geol. and Nat. Res.)

GREENE, G. K. 1906—On the age of the rocks near Kentland, Indiana. Contr. to Indiana Paleontology **2**(1):11-17.

KINDLE, E. M. 1903—The Niagara domes of northern Indiana. Amer. Jour. Sci. **15**(4):459-468.

———1904—The stratigraphy and paleontology of the Niagara of northern Indiana. Ind. Dept. Geol. and Nat. Res., **28**th Ann. Rept. :397-428.

KINDLE, E. M. AND C. L. BREGER. 1904—Paleontology of the Niagara of northern Indiana. Ind. Dept. Geol. and Nat. Res., **28**th Ann. Rept. :428-486 and plates.

LAMAR, J. E. 1928—Geology and economic resources of the St. Peter sandstone of Illinois. Ill. Geol. Surv. Bull. **53**:175 pp.

LEY, H. A. (Ed.) 1935—Geology of Natural Gas ("Lima-Indiana district, Indiana and Ohio"). Amer. Assoc. Petr. Geol. Pub. :1127 pp. [843-852].

LLOYD, C. H. 1931—Middle Ordovician fauna from the disturbed area three miles southeast of Kentland, Indiana. A. M. Thesis, University of Wisconsin, (Unpublished).

LOGAN, W. N. 1922—Geological Map of Indiana.

———1922a—Economic geology of Indiana. Handbook of Indiana Geology Pt. **5**:571-1058.

———1926—The geology of the deep wells of Indiana. Conserv. Comm. (Indiana), Div. Geol., Pub. **55**:1-540.

———1931—Sub-surface strata of Indiana. Conserv. Comm. (Indiana), Div. Geol., Pub. **108**:1-790.

——1932—Geological Map of Indiana. Conserv. Comm. (Indiana), Div. Geol., Pub. **112**.

ORTON, E. 1889—The Trenton limestone as a source of petroleum and inflammable gas in Ohio and Indiana. U. S. Geol. Surv., 8th Ann. Rept. (pt. 2):475-662.

PHINNEY, A. J. 1891—The natural gas field of Indiana. U. S. Geol. Surv., 11th Ann. Rept. (pt. 1):579-742.

REEVES, J. R. 1925—The production of oil in Indiana. Bull. Amer. Assoc. Petr. Geol. **9**:317-325.

SHROCK, R. R. AND C. A. MALOTT. 1930—Notes on some northwestern Indiana rock exposures. Proc. Ind. Acad. Sci. **39**:221-227.

——1933—The Kentland area of disturbed Ordovician rocks in northwestern Indiana. Jour. Geol. **41**:337-370.

SHROCK, R. R. AND G. O. RAASCH. 1935—Correlation of Ordovician sequence at Kentland, Indiana. Proc. Geol. Soc. Amer. for **1934**:355-356.

THOMPSON, M. 1889—The Wabash Arch. Ind. Dept. Geol. and Nat. Hist., 16th Ann. Rept. :41-53.

——1892—Geological and natural history report of Carroll County. Ind. Dept. Geol. and Nat. Res., 17th Ann. Rept. :171-191.

TWENHOFEL, W. H. 1931—Environment in sedimentation and stratigraphy. Bull. Geol. Soc. Amer. **42**:407-424.

VER WIEBE, W. A. 1929—Unconformity at top of Trenton in Lima, Indiana, district. Bull. Amer. Assoc. Petr. Geol. **13**:688-689.

WARD, L. C. 1906—The roads and road materials of the northern third of Indiana. Ind. Dept. Geol. and Nat. Res., 30th Ann. Rept. :161-274.

WILSON, C. W. JR., AND K. E. BORN. 1936—The Flynn Creek disturbance, Jackson County, Tennessee. Jour. Geol. **44**:815-835.

Supported in part by a grant from the Wisconsin Alumni Research Foundation.

Paleontology of the Disturbed Ordovician Rocks near Kentland, Indiana[1]

Robert R. Shrock and Gilbert O. Raasch

Introduction

The stratigraphy and structure of the area of disturbed Ordovician rocks 3 miles east of Kentland, Newton County, Indiana, are considered in a previous paper,[1] which includes the figures referred to in the following discussion. There remain the description and illustration of the fossils collected in the area.

Fossils were collected from 3 quarries, whose relations are shown in Fig. 1. The westernmost of these is called the *Means;* the easternmost, the *McKee.* Both are now abandoned, though the strata are accessible. The large middle quarry, long known as the *McCray* but now usually called the *Kentland* quarry, is being operated. The older name, McCray, is used in the following descriptions.

Review of Previous Work

While there have been numerous references to fossils found at Kentland, few of the species have been described and illustrated. The first reference was that of Collett (1883, 58-59)[2] who reported that G. K. Greene had identified several Ordovician fossils from Kentland. The specimens, which were collected in the McKee quarry, were identified as *Tetradium fibratum, Zygospira modesta, Streptorhynchus, Leperditia, Ptilodictya, Orthoceras* and *Glyptocrinus.*[3]

Gorby (1886, 236) later reported a somewhat different assemblage from the same quarry, including *"Orthoceras simulator, Orthoceras annulatum, Gyroceras* (or *Lituites),* and *Orthis testudinaria."* On the basis of this fauna he assigned the strata in the McKee quarry to both the Silurian and Ordovician. Concerning the numerous delicate Ordovician fossils which occur in argillaceous films between the limestone layers, he wrote: "There are also several species of Lower Silurian fossils found in this quarry, consisting of delicate bryozoans, or the single values [valves] of *Orthis testudinaria.* These are invariably found in the seams between the layers of stone, attached slightly to the sides of the strata by a calcareo-argillaceous cement. They are never

1 For stratigraphy and structure, see Shrock, This Journal.

2 See Bibliography at end of preceding paper.

3 These and other species which have been reported from Kentland by numerous writers will be found listed in an Appendix, with all changes in generic and specific references indicated.

found embedded in the stone. They have evidently been carried up through crevices in the rocks by the force of escaping steam or gas from below."

We have found none of the genera reported by Gorby, nor any others indicating that the rocks are of Silurian age. So far as we are aware, no other investigators who have visited the Kentland quarries within the last three decades have found such fossils. On the contrary, species found in the argillaceous films, like those in the limestone beds themselves, are of Ordovician age and give no evidence of having reached their present position in the manner suggested by Gorby.

Kindle and Breger (1904, 470-471) described and figured a new cephalopod, *Orthoceras (Kionoceras) kentlandensis,* from the Kentland locality, but unfortunately did not state from which quarry it was collected.

Until 1906 geologists seem totally to have disregarded Greene's discoveries as reported by Collett (1883, 58-59), and referred the Kentland rocks to the Silurian. In this year, however, Greene (1906, 11-17) himself produced evidence to support his earlier findings. This evidence consisted of several illustrations showing *Escharopora, Rhinidictya, Helopora, Poterioceras kentlandense, Leperditia fabulites* and *Leperditella.* With these specimens, found in the McKee quarry, Greene correctly correlated the strata with the Ordovician. The specimens were photographed and identified by R. S. Bassler,[4] though Greene did not acknowledge his assistance.

In spite of Greene's report, the strata at Kentland continued to be referred to the Silurian until Foerste (1921, 277-278) pronounced them Ordovician on the basis of a fauna containing *Columnaria halli, Rafinesquina minnesotensis, Strophomena minnesotensis, Zygospira recurvirostris, Ctenodonta nasuta, Actinoceras beloitense, Isotelus* cf. *platycephalus* and *Thaleops ovatus.* These fossils were collected from a brownish-gray, fine-grained limestone (probably Div. 4 or 6) "resembling some phases of the Plattin limestone of eastern Missouri." Foerste did not state whence the specimens came, and he did not collect them himself. We think it likely, however, that the fauna came from the McCray quarry.

In 1930 Shrock and Malott (1930, 222) reported "14 species, in addition to those listed by Greene and Foerste, from the westernmost of the three quarries [Means], and all are typical forms in the Black River—Trenton series of Minnesota. The strata in the two abandoned quarries [Means and McKee] have been found to be the same. It is almost certain that they represent rocks of Black River—Trenton age, and it is also very likely that rocks of the same age occur in the larger active quarry [McCray]."

In 1933 Shrock and Malott (1933, 346-358) listed 8 species from the McKee quarry, 19 species from the Means quarry, and some 50 species from various parts of the McCray quarry. They (p. 351) reported that G. O. Raasch had identified the following fossils from the fossiliferous sandstone in the south wall of the McCray quarry: "*Endoceras* sp., *Liospira* sp., *Modiolopsis* (2 species), *Orthodesma* sp., *Sphenolium* n. sp., and *Triptoceras* [*Trip-*

4 Personal communication, October 14, 1935.

teroceras] sp." Comments on these genera, as well as the others reported from the locality, will be found in the Appendix at the end of this report. In addition to listing the several faunas, the authors erected a provisional stratigraphic column for the disturbed area. This includes formations ranging in age from Oneonta ? to Galena inclusive.

Foerste (1932; 1933, 73) described and figured a new cephalopod, *Kentlandoceras schrocki*, the genotype of which is a specimen sent him by the senior author. The correspondence concerning this specimen was reported by Shrock and Malott (1933, 355) after the new genus had been described.

Review of Species

The reader is referred to the preceding paper for detailed description of the units and divisions of the generalized stratigraphic column constructed for the disturbed area.

Coelenterata

ANTHOZOA[5]

Streptelasma profundum (Conrad)

Cyathophyllum profundum Conrad, Proc. Acad. Nat. Sci. Philadelphia, **1**, 1843; 355. Owen, Geol. Iowa, Wisconsin, and Illinois, 1844, pl. 16, fig. 5.

Streptoplasma profunda Hall, Pal. New York, **1**, 1847: 49, pl. 12, figs. 4a-d.

Streptelasma profunda Edwards and Haime, Mon. d. Polyp. Foss. d. Terr. Pal. (Arch. du Mus. d'Hist. Nat., **5**), 1851: 400.[6]

Comments.—A single internal filling, showing the characteristic form of this species, was collected from the molluscan zone along the east wall of the McCray quarry.

Occurrence.[7]—Black River of the United States. Kentland, Indiana.

---

5 Mr. Shrock identified, described and photographed the Coelenterata, Bryozoa, Brachiopoda (in part), Cephalopoda (in part), and Arthropoda. Mr. Raasch identified, described and assisted in the photographing of the Mollusca, and aided in the identification of some Brachiopoda and Arthropoda. Mr. C. H. Lloyd made a preliminary study of the specimens from the McKee and Means quarries, but should not be held responsible for identifications in the present report, since the authors have restudied all material.

New species are attributed to one or the other of the present authors, not to both jointly.

Acknowledgements are due the Wisconsin Alumni Research Foundation and the Milwaukee Public Museum for financial and photographic aid respectively.

6 A complete synonymy may be found in Bassler's "Bibliographic Index of American Ordovician and Silurian Fossils" (U. S. Nat. Mus. Bull. **92**, 1915). References here include: (1) original description of the species; (2) original figures of the species if they are not included in (1); (3) the most recent generic reference if there has been a change in the genus; and (4) supplementary figures or descriptions which add important information to (1) and (2). In cases where it is deemed necessary, the original description, or a portion of it, is quoted *verbatim*, and is followed by either a more recent and complete description or by comments on the Kentland specimens. Lengthy descriptions are avoided.

7 Unless otherwise stated, data on occurrence and horizon are taken from Bassler U. S. Nat. Mus. Bull. **92**, 1915.

Columnaria halli Nicholson

Plate 1, Figs. 1-3

Columnaria—Emmons, Geol. New York, Rep. 2nd dist., 1842: 276, fig. 2.

Columnaria alveolata Hall, Pal. New York, **1**, 1847: 47, pl. 12, figs. 1a-1c.

Columnaria (?) *Halli* Nicholson, Tab. Corals Pal. Period, 1879: 200, fig. 28, 2; 201, fig. 29; pl. 10, figs. 3, 3a.

Columnaria halli Foerste, Denison Univ. Bull., Jour. Sci. Lab., **19**, 1921: 278.

Comments.—Coralla of this species are common in Divs. 9 and 10 at Kentland. A small, poorly preserved corallum about 1.5 inches in diameter was found along the north wall of the McCray quarry, and a larger colony, about 8 inches in diameter and well preserved by silicification, was collected from a small fault block in the southwestern corner of the same quarry. A dozen or more silicified coralla were collected from the floor of the McCray quarry just north of the sump (Plate 2, preceding paper) and a single specimen was found in the thin-bedded, semi-lithographic limestone of Div. 8 (22) just west of the ramp. Kentland specimens show the distinctive features of the species.

Occurrence.—Black River and Trenton: Illinois, Iowa, Kentucky, Michigan and Minnesota. Kentland, Indiana: Divs. 8 (22), 9 and 10, McCray quarry.

Tetradium cellulosum (Hall)

Plate 1, Fig. 4

Phytopsis cellulosum Hall, Pal. New York, **1**, 1847: 37, 315, pl. 9, figs. 1, 1a-d.

Tetradium cellulosum Dwight, Trans. Vassar Bros. Inst., **5**, 1890: 76.—Ruedemann, Amer. Geol., **22**, 1898: 16-25, pl. 5, figs. 1-16a.— Shrock and Mallott, Jour. Geol., **41**, 1933: 346.

Comments.—The Kentland forms of this species are either flat, ribbonlike or round, rodlike, single or branching coralla which in most cases lie parallel to the bedding planes. Cross-sections of these coralla show them to be composed of 4 large (more than 1 mm. in diameter) or 16 smaller (less than 1 mm. in diameter) four-sided corallites. Each corallite has either 4 plications, in which case the plications are usually not large; or 12, in which case there are 4 primary plications which reach almost to the center of the corallite, and 8 smaller, shorter secondary plications arranged symmetrically with respect to the primary plications. The latter corallites, according to Raymond, have almost reached the stage of fission when 4 new corallites will arise from the single preexisting corallite.

Longitudinal sections show that the corallites are thin-walled, with the wall material usually in the form of fairly coarsely crystalline calcite, and that they may or may not have the tabulae preserved. Some very well preserved specimens show thin, transparent tabulae from 1 to 2 mm. apart. Ordinarily, however, tabulae are wanting, apparently because of destruction during fossilization.

Occurrence.—Black River (Lowville): Alabama, Kentucky, New York

and Pennsylvania; Canada. Kentland, Indiana: Div. 8 (17), McKee, Means and McCray quarries; Div. 9, McCray quarry.

STROMATOPOROIDEA

Cryptophragmus antiquatus Raymond

Plate 2, Figs. 1-3

Cryptophragmus antiquatus Raymond, Can. Geol. Surv., Mus. Bull. **5**, geol. ser. **21**, 1914: 3, pl. 1, figs. 1-4; pl. 2, figs. 1-2; pl. 3, figs. 1-5; pl. 4, figs. 1-5.—Shrock and Malott, Jour. Geol., **41**, 1933: 347 ff.

Description.—Colonial organisms, presumably Hydromedusae, of elongate, upright, unbranched form, small diameter, and slight taper. Skeleton consisting of internal camerate tube with distinct wall, the tube crossed by irregularly spaced partitions which are convex upward, and further strengthened by a deposit of incomplete partitions (cystose material) on the inner side of the wall of the tube. The inner tube enveloped by concentric, often slightly separated sheaths of calcareous material, the sheaths traversed by numerous circular openings at right angles to the long axis of the colony. The sheaths extend over the upper end of the inner tube, which may be enlarged and bulblike.

Comments.—Raymond reported his specimens from "just below the range of *Tetradium cellulosum* and *Bathyurus extans*, and, therefore, just below the base of the Lowville." This species has been reported by him from Aylar, Quebec; Mechanicsville, Ontario; Town of Carden, east of Lake Simcoe, Ontario; and Clayton, New York. Butts[8] recently reported this species from the Chickamauga (Black River) limestone of Alabama, associated with *Tetradium cellulosum*. In his description of the species on page 128, he stated: "These forms [referring to *C. antiquatus*] are supposed to be allied to certain genera of fossil sponges. . . . This is one of the main guide fossils of the Lowville horizon from Canada to Alabama."

The Kentland specimens usually show only the central tabulated tube, which is exactly like those figured by Raymond, but in a few specimens a very small portion of the larger enveloping sheaths remains. Apparently most of the outer sheaths were destroyed during fossilization.

Several specimens which apparently belong to the species *antiquatus* show the following dimensions, in millimeters:

Length	35	35	135	100	30	1.9	32	15	25	
Diameter	3.5	3.5	8	6	8	8	9	9	10	
Tabulated tube (diameter)	3.5	3–4			5	4	6.5	7	5	
Cystose zone (width)	.1				1.5	1	1.25	1		.5–2
Clear zone (width)						.75			1	
No. of tabulae	12				8	5	10	4	8	
No. of chambers	10				8	5	10	4	8	

Though at least two of the specimens are less than half the diameter of the average, the internal structure of all these specimens appears to be identical, hence the small ones may not be referred to another species. Recently,

8 Butts, Charles, Geology of Alabama, Geol. Surv. Ala., Spec. Rept. **14**:119, pl. 32, figs. 4-7, 1926.

Raymond[9] erected several new genera and species and discussed several other genera, among them *Beatricia gracilis*, which was first named by Ulrich and described and figured by Foerste. This fossil seems to have much the same internal structure as *C. antiquatus*, but differs from that genus "in lacking the radial zone and in being much more slender." Since there is no radial zone preserved in the Kentland specimens, if indeed one was present, and since those specimens in some cases are much smaller than the dimensions given for *C. antiquatus*, it may be that the smaller forms should be referred to *B. gracilis*. Because of the similarity of structure between the largest and smallest forms, however, we think it best to refer all specimens to *antiquatus*.

Occurrence.—Just below the Lowville (Upper Pamelia): Quebec and Ontario, Canada; and Clayton, New York. Chickamauga (Black River), Alabama. Kentland, Indiana: Div. 7, McKee, Means and McCray quarries.

Kentlandia Shrock gen. nov.

In Div. 7 of the Means and McCray quarries, there occurs, closely associated with *Cryptophragmus antiquatus*, a coralline organism which does not appear to belong to any described genus. Shrock and Malott[10] listed this fossil, which is represented by two somewhat dissimilar forms, as *Beatricia* n. sp. and *Tetradium carterensis*. These two dissimilar forms are members of a new genus. A description of the new genus, named after the town west of the quarries, follows.

Description.—Single or branching coralla consisting of round or sub-round, fairly straight and in some cases flaring, slowly enlarging stems or masses, which are composed of bundles of polygonal, sub-triangular or sub-oval, tubular corallites arranged about and parallel to a prismatic corallite, no larger than the surrounding ones, occupying an axial position in the stem. The corallites show neither septa nor tabulae and the walls are imperforate. In well preserved specimens there frequently is a radial growth of calcite crystals on the inner side of the outer convex wall of the corallite. The corallites are arranged in poorly defined circlets about the central tubular corallite, and the outer walls of one circlet form the inner concave walls of the next outer circlet, so that in transverse section the stem of a single or branching corallum has a scalloped appearance because of the imbrication of the corallites (Plate 1, Figs. 5-13; Plate 2, Figs. 4-8). In longitudinal section the corallites do not change greatly in size. Many of the corallites are filled with fairly coarsely crystalline calcite. Genotype: *Kentlandia imbricata* gen. and sp. nov.

Comments.—The distinct radial arrangement of calcite crystals on the inner side of the curved wall (Plate 1, Figs. 5-6, 13) is similar to that described by Nicholson[11] for *Beatricia nodulosa*, and the arrangement of the corallites,

9 Raymond, P. E., "Notes on invertebrate fossils with descriptions of new species. 3. Further notes on Beatricia-like organisms," Bull. Mus. Comp. Zool. (Harvard), **55**:177-184, plates, 1931.

10 Shrock, R. R. and Malott, C. A., "The Kentland area of disturbed Ordovician rocks in northwestern Indiana," Jour. Geol., **41**:347, 357, 360, 1933.

11 Nicholson, H. A., A Monograph of British Stromatoporoids, 1886, pl. 8, fig. 5.

when seen in transverse section, is similar to that in the same genus; but the Kentland specimens lack the central, tabulated tube characteristic of *Beatricia*.

Bassler[12] recently figured a coral—*Tetradium carterensis*—from the Carters limestone of Tennessee. His figures, which show a poorly preserved specimen, closely resemble one of the two species of *Kentlandia*, but his description[13] shows that the Tennessee specimen is different from the Kentland forms. Okulitch[14] has erected a new genus, *Paleoalveolites*, to replace the *Tetradium* ? of Bassler and described the specimens from Tennessee in greater detail. The presence of a probable columella, of septa and of tabulae, and the fact that the calices open obliquely to the surface, are sufficient to show that the Kentland specimens, while apparently related to *Paleoalveolites*, are generically different. We can not state whether *Kentlandia* is a coral or a stromatoporoid, though we favor its reference to the latter because of its internal structure.

Kentlandia imbricata Shrock sp. nov.

Plate 1, Figs. 5-13; Plate 2, Fig. 4

Beatricia n. sp. Shrock and Malott, Jour. Geol., **41**, 1933: 347 ff.

Description.—Single corallum composed of a round or sub-round, straight, slowly tapering stem which comprises a bundle of sub-triangular, tubular corallites, having an outer convex wall and 2 or more inner concave walls, arranged about and parallel to a central, roughly prismatic tube, no larger than the surrounding ones, lying along the axis of the stem. The outer convex wall is usually the most prominent and in well preserved specimens has a band of radially disposed calcite crystals on the inner side (Plate 1, Figs. 5, 6 and 13). The corallites are disposed about the central tube in poorly defined circlets, giving the corallum, when seen in transverse section, a scalloped appearance. Each circlet of corallites imbricates on the preceding, and the outer convex walls of the corallites in one circlet form the inner concave walls of the carallites of the next succeeding circlet. In some parts of the corallum the corallites may have the outer wall convex, but the inner ones straight (Plate 1, Fig. 9).

The radial structure on the inner side of the outer convex walls of the corallites, distinctive of this species, consists of interlocking, platy calcite crystals which extinguish differently. They give rise to a dark band within the convex wall. Very frequently part or all of the corallite is filled with fairly coarsely crystalline calcite (Plate 1, Fig. 9). The corallites show neither septa nor tabulae and the walls are imperforate.

The corallites range in greatest diameter from less than 1 mm. to 2 or 3 mm. (rarely twice the latter numbers in the peripheral zones of some

12 Bassler, R. S., "The stratigraphy of the Central Basin of Tennessee," State of Tennessee, Dep. Ed., Div. Geol., Bull. **38**: pl. 7, figs. 2-3, 1932.

13 Bassler, R. S., Descriptions of Paleozoic fossils from the Central Basin of Tennessee, Jour. Wash. Acad. Sci., **25**:405, 1935.

14 Okulitch, V. J., Tetradidae—A revision of the genus Tetradium, Trans. Royal Soc. Canada, **19**:64-66, pl. 2, figs. 1-4, 1936.

coralla), and reach lengths of 6 cm. or more without changing greatly in size. The coralla range in greatest diameter from 1 to 3 or 4 cm. and specimens measuring 8 cm. have been found. Neither the top nor the base of a corallum has been seen. No branching coralla have been found.

The distinctive features of this species are the pronounced imbrication (whence the name of the species) of the curved, convex walls of the corallites, the fairly regular arrangement of the corallites about the central one, the marked development of radial structure on the inner side of the outer convex wall of numerous corallites, and the smaller size of the corallum as compared with that of the species to be described next as *K. irregularis*.

Occurrence.—Kentland, Indiana: Div. 7, Means and McCray quarries. (Holotype, No. 501, Geological Museum, University of Wisconsin).

Kentlandia irregularis Shrock sp. nov.
Plate 2, Figs. 5-8

Tetradium carterensis Shrock and Malott, Jour. Geol., **41**, 1933: 357, 359-360.

Description.—Single or branching coralla of regular or irregular growth, composed of trunk-like or irregularly pyriform masses from 3 cm. to 25+ cm. in greatest diameter, and as much as 25 cm. in length. Neither the top nor the base of a corallum has been seen. The broken coralla, which lie in a prostrate position parallel with the bedding, are composed of prismatic or subprismatic corallites which are arranged in very poorly defined circlets about the axis of the corallum (Plate 2, Fig. 7). Because of the poor preservation, it is not known whether there is an axial tube or corallite as in *K. imbricata*. Corallites vary in greatest diameter from less than 1 mm. to more than 4 mm., and in length may exceed 5 cm. Neither septa nor tabulae have been seen and the corallite walls are imperforate and very slightly rugose. The corallites, in transverse section, may be polygonal with all sides or walls straight, or they may be sub-triangular with the outer wall convex and the inner ones straight. No radial structure has been seen in any specimens, but the poor state of preservation may account for its absence.

The very irregular shape and arrangement of the corallites and the irregularly pyriform shape of many coralla are characteristic. Coralla attain much larger size than in *K. imbricata* and are known to branch.

Comments.—The specimens included in this species are the ones reported by Shrock and Malott[15] as *Tetradium carterensis*. It is now known that the Kentland specimens do not comprise a species of the genus *Paleoalveolites*, which was erected to include *Tetradium carterensis* when it was found that the latter was not a *Tetradium*, but belong to the genus *Kentlandia* described above. Well preserved specimens of *K. irregularis* might show most of the features of *K. imbricata*, but on the basis of the material at hand it seems best to recognize two species.

Occurrence.—Kentland, Indiana: Div. 7, McCray quarry. (Holotype, No. 502, Geological Museum, University of Wisconsin).

15 Shrock, R. R. and Malott, C. A., *Ibid.*, 1933, pp. 357, 359-360.

Bryozoa

Rhinidictya exigua Ulrich

Plate 3, Fig. 9

Rhinidictya exigua Ulrich, Jour. Cincinnati Soc. Nat. Hist., **12**, 1890: 184, fig. 9; Geol. Minnesota, **3**, 1893: 131, pl. 8, figs. 6-10.

Comments.—This is not a common species at Kentland but the 3 or 4 specimens found agree closely with Ulrich's description and figures.

Occurrence.—Black River (Decorah): Minnesota. Kentland, Indiana: Div. 8 (15), Means quarry.

Rhinidictya mutabilis (Ulrich)

Plate 3, Fig. 10

Stictopora mutabilis Ulrich (part), **14**th Ann. Rep. Geol. Nat. Hist. Surv. Minnesota, 1886: 66.

Rhinidictya mutabilis Ulrich, Geol. Minnesota, **3**, 1893: 125, pl. 6, figs. 1-6, 12, 13; pl. 7, figs. 10-23, 25-28; pl. 8, figs. 1-3.—Shrock and Malott, Jour. Geol., **41**, 1933: 346, 348.

Description.—Rhinidictya mutabilis, according to Ulrich (1893, p. 125), has the "Zoarium a branching bifoliate stipe, varying considerably in width and superficial aspect." Because of its variation, and also because Ulrich's original description is long, it is not quoted. The Kentland specimens, which are not very numerous, show the essential features of the species both superficially and in thin section. They agree closly with forms reported by Ulrich from the Decorah and Prosser.

Occurrence.—Black River (Decorah) and Trenton (Prosser): Iowa and Minnesota. Kentland, Indiana: Div. 8 (17-18), McKee quarry and Div. 8 (15), Means quarry.

Rhinidictya trentonensis (Ulrich)

Dicranopora trentonensis Ulrich, Jour. Cincinnati Soc. Nat. Hist., **5**, 1882: 167, pl. 6, figs. 15, 15a.

Rhinidictya trentonensis Ulrich, Geol. Minnesota, **3**, 1893: 135, pl. 6, figs. 14-18.

Comments.—This species is represented sparingly at Kentland. It occurs as small fragments of the zoarial branches.

Occurrence.—Stones River (Lebanon) of Tennessee and Black River (Platteville) of Illinois, Minnesota and Wisconsin. Kentland, Indiana: Div. 8 (15), Means quarry.

Escharopora angularis Ulrich

Plate 3, Figs. 13, 16

Escharopora angularis Ulrich, Geol. Minnesota, **3**, 1893: 168, pl. 12, figs. 1-4, 30, 31.—Shrock and Malott, Jour. Geol., **41**, 1933: 347.

Comments.—The Kentland fauna contains a number of well preserved examples of this species.

Occurrence.—Black River (Platteville and Decorah): Kentucky and Minnesota. Kentland, Indiana: Div. 8 (15), Means quarry.

Escharopora recta Hall

Plate 3, Figs. 6-7

Escharopora recta Hall, Pal. New York, **1**, 1847: 73, pl. 26, figs. 1a-g.—Shrock and Malott, Jour. Geol., **41**. 1933: 347.

Comments.—This species is abundant in the Means quarry and in some beds along the north wall of the McCray quarry. The zoaria are moderately tapering, falciform, straplike stems whose surface is characterized by many zooecial apertures which have hexagonal outlines when well preserved and which are arranged in a symmetrical, quincuncial fashion. The following measurements were obtained from several specimens:

40 rows of zooecia in 5 mm. transversely
22 rows of zooecia in 5 mm. longitudinally
18 rows of zooecia in 5 mm. diagonally

The curved zoaria range in length from 10 to 60 mm., and in width from 2 to 5 mm. They appear considerably flattened, seldom exceeding 1 mm. in thickness.

Occurrence.—Trenton: Minnesota and New York; Canada. Kentland, Indiana: Div. 8 (15, 17), Means and McCray quarries.

Escharopora subrecta (Ulrich)

Plate 3, Fig. 5

Ptilodictya subrecta Ulrich, **14**th Ann. Rep. Geol. Nat. Hist. Surv. Minnesota, 1886: 63.

Escharopora subrecta Ulrich, Geol. Minnesota, **3**, 1893: 168, pl. 12, figs. 5-29.—Shrock and Malott, Jour. Geol., **41**: 1933, 347.

Comments.—This species is represented by a number of fairly well preserved specimens in the Kentland fauna.

Occurrence.—Black River (Decorah): Ontario; Iowa; Minnesota; and Wisconsin. Kentland, Indiana: Div. 8 (15), Means quarry.

Helopora alternata Ulrich

Plate 3, Fig. 2

Helopora alternata Ulrich, Jour. Cincinnati Soc. Nat. Hist., **12**, 1890: 192, fig. 16f.; Geol. Minnesota, **3**, 1893: 192, pl. 3, fig. 9.

Description (1890).—Zoarium jointed; segments exceedingly slender, slightly curved, about 3.0 mm. long and 0.5 mm. in diameter; lower extremity obtusely pointed. Zooecial apertures oval, direct, impressed, comparatively large, 0.14 mm. long, arranged alternately, four in each cycle, twelve cycles in 2.5 mm. Interspaces rather thin, generally appearing simply rounded. On the segment illustrated two faint impressed lines wind between the apertures near the base.

The very thin segments, and large alternately or quincuncially arranged zooecia impart to this species a very characteristic and easily recognized appearance.

In his Minnesota report Ulrich states that the length of the stem is 5 mm., the width, 0.25 mm., and that the zooecial apertures number "twelve or thirteen in a direct line 5 mm. long." The Kentland specimens average 3 mm. in length and 0.3 mm. in width, and have 12 cycles of zooecial apertures in

2.5 mm. and 6 zooecial apertures longitudinally in 2.5 mm. The small size of the segments and the large zooecia are distinctive.

Occurrence.—Black River (Decorah): Minnesota. Kentland, Indiana: Div. 8 (15), Means quarry.

Helopora mucronata Ulrich

Plate 3, Fig. 1

Helopora mucronata Ulrich, Jour. Cincinnati. Soc. Nat. Hist., **12**, 1890: 192, fig. 16e; Geol. Minnesota, **3**, 1893: 193, pl. 3, fig. 10.—Shrock and Malott, Jour. Geol., **41**, 1933: 347.

Description (from second reference which differs from the original by a few slight modifications and additions).

Segments spine-like, slightly curved, 3.5 to 4.0 mm. long, tapering downward from the truncate upper end, where the diameter is 0.6 or 0.7 mm., to the acute and finely striated basal extremity. Zooecial apertures oblique, the inferior and lateral margins elevated, arranged longitudinally and spirally, with from six to eight forming a complete volution, and six in about 2.5 mm. lengthwise. Above each zooecial aperture two short striae. Obscure longitudinal ridges sometimes formed by the coalescence and continuance of the elevated lateral margins of the zooecial apertures.

The Kentland specimens are slightly longer (5 mm.), and slightly slenderer (0.6 mm. to 0.5 mm.) than the Minnesota forms, but are in close agreement otherwise.

Occurrence.—Trenton (Prosser): Minnesota. Kentland, Indiana: Div. 8 (15), Means quarry.

Helopora spiniformis (Ulrich)

Plate 3, Figs. 3, 11-12, 15

Arthroclema spiniforme Ulrich, Jour. Cincinnati Soc. Nat. Hist., **5**, 1882: 161, pl. 6, figs. 10, 10a.

Helopora spiniformis Ulrich, Geol. Minnesota, **3**, 1893: pl. 3, figs. 4, 5, 6.

Comment.—The Kentland specimens show considerable variation in the number of longitudinal rows of zooecia (2-5 visible on a prostrate branch); the number varying from 5-10. The poor preservation of the segments prevents observation of surface characteristics. The zoarial segments, when intact, are bluntly rounded at the lower extremity, rather flatly truncated at the upper, and average 5-8 mm. in length, with an average width of 0.6-0.75 mm. There are 12 transverse rows of zooecial apertures in 5 mm. and from 4-5 longitudinal rows in 0.75 mm. In spite of considerable variation, due in part to surface weathering of the zoaria, there are numerous specimens which agree closely with the described figures.

Occurrence.—Stones River (Lebanon); Tennessee. Kentland, Indiana: Div. 8 (15), Means quarry.

Helopora pulchella Shrock sp. nov.

Plate 3, Fig. 4

Description.—Segment long, slender, round and slightly curved. It tapers gradually from a truncated anterior extremity to a rounded, slightly pointed

basal extremity. Length, 5-10 mm., diameter, 0.5-0.8 mm. The zooecial apertures, disposed in longitudinal and spiral rows, have a quincuncial arrangement. This arrangement is not as pronounced near the base as in the upper three-fourths of the segment. There are from 6 to 10 zooecial apertures in one volution; 3 to 4 in 1 mm. measured along a diagonal row. There are 10 zooecial apertures in 5 mm. measured along a longitudinal row. The apertures are small, subelliptical and slightly directed toward the basal extremity. They are separated longitudinally by rather thick, rounded ridges which extend the full length of the segment; and transversely by elevated, rounded, cup-like ridges. No surface striations are apparent because of the weathered condition of the specimens.

H. pulchella resembles *H. alternata* Ulrich, from the Decorah of Minnesota, in the distinctive quincuncial arrangement of the zooecial apertures, but differs from that species in the greater number of longitudinal rows of zooecia and the comparatively smaller zooecial apertures. It is also close to *H. mucronata* Ulrich, from the Prosser of Minnesota, from which it differs in being much longer and in having a much more pronounced quincuncial arrangement of the zooecial apertures and more rows per volution. Finally, it shows some resemblance to *H. spiniformis* (Ulrich), from the Stones River (Lebanon) of Tennessee, but it is much slenderer, has fewer longitudinal rows of zooecia, and has the zooecial apertures in spiral rather than in transverse rows.

Occurrence.—Kentland, Indiana: Div. 8 (15), Means quarry. (Holotype, No. 503, Geological Museum, University of Wisconsin.)

Nicholsonella pulchra Ulrich
Plate 3, Fig. 8

Nicholsonella pulchra Ulrich, Geol. Minnesota, 3, 1893: 314, pl. 21, figs. 8-12.

"*Internal characters:* In vertical sections the tubes diverge with comparative rapidity and uniformity of curvature. Their walls are thin, though not excessively so, and exhibit that lack of sharpness which characterizes especially the Trenton species of the genus. Young zooecial tubes arise in the axial region mainly and expand very gradually. Diaphragms occur throughout, two or three times their diameter apart in the axial region, and averaging nearly twice as many in a given space in the peripheral region. In young examples it is not easy to distinguish the mesopores from the true zooecial tubes, but the solid deposit which more or less completely fills up the outer part of the mesopores in the fully matured stages then renders the task an easy one. This deposit is lined vertically with rows of dots, and in many cases is divided up into two or more layers with light intervals between them. The two halves of fig. 10 show, in the upper, the structure of a matured example just beneath the surface. Here the zooecia are as usual not sharply defined and the interspaces completely filled with solid tissue in which a great number of small dots (representing the superficial papillae) are to be observed. At a deeper level in the zoarium (see lower half of fig. 10) the large angular mesopores are open. Here even some dots (? acanthopores) are to be made out in the walls, chiefly at the angles of junction."

Comment.—Several fragmental zoaria of this species are included in the Kentland fauna. They are not well preserved, but thin sections show the important features necessary for their identification. The camera lucida drawing (Plate 3, Fig. 8) attempts to show the structure observed in a tangential section just beneath the surface. The small dots represent the superficial papillae mentioned in Ulrich's description. Although some mesopores are very faintly suggested in our sections they were not sufficiently clear to allow delineation of their outlines. Our vertical sections are too poorly preserved to show more than the general structures.

Occurrence.—Stones River (Pierce): Tennessee. Kentland, Indiana: Div. 5, McCray quarry.

Brachiopoda

Crania setigera Hall

Plate 3, Figs. 14, 18-19

Crania setigera Hall, Descriptions n. sp. Crinoidea and other Fossils, 1866, p. 12; **24**th Rep. New York State Cab. Nat. Hist., 1872, p. 220, pl. 7, fig. 15.

Description.—Shell small, suborbicular; length greater than width; cardinal margin nearly straight. Dorsal valve convex; beak elevated, pointed, situated nearly one-third the length of the valve from the cardinal border.

Surface marked by comparatively coarse pustules or setae, which are more distant [distinct?] near the margin of the shell.

Comments.—This small brachiopod is represented by several fairly well preserved but fragmentary valves. The pustules mentioned by Hall are very prominent especially near the margin.

Occurrence.—Black River (Platteville and Decorah): Iowa; Minnesota, Wisconsin. Kentland, Indiana: Div. 8 (15), Means quarry.

Pholidops trentonensis minor Winchell and Schuchert

Plate 3, Fig. 20

Pholidops trentonensis var. *minor* Winchell and Schuchert, Geol. Minnesota, **3**, 1893: 376, pl. 29, fig. 40.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—The original description of *P. trentonensis* Hall is as follows: 'Shell small, broadly oval, very depressed-convex. Apex situated near the cardinal extremity. Surface marked by strong, concentric, lamellose lines of growth.'

The Minnesota specimens in outline, convexity of valves, position of the apex and the strong lamellose lines of growth, agree with these parts as described and illustrated in *P. trentonensis* Hall. They are, however, one-half, but more often less than one-half the size attained by this species as found at Middleville, New York, and since they are constantly smaller, the varietal name *minor* is here applied to them. The growth lines are conspicuous in some specimens, while in others they are nearly obsolete. The muscular markings are undefined, owing to the tenuity of the valves.

Comments.—A single specimen is referred to this species. It is 2 mm. wide, 2.5 mm. long, and is in the form of an impression of the surface of a dorsal (?) valve. The lamellose growth lines are distinct in the impression, though they do not show clearly on the photograph. In size the Kentland specimen closely resembles the variety *minor*.

Occurrence.—Trenton (Prosser): Minnesota. Kentland, Indiana: Div. 4-6, McCray quarry, where it is associated with *Zygospira saffordi.*

Hesperorthis tricenaria (Conrad)

Plate 3, Figs. 21-24

Orthis tricenaria Conrad, Proc. Acad. Nat. Sci. Philadelphia, **1**, 1843: 333.—Hall, Pal. New York, **1**, 1847: 121, pl. 32, fig. 8.—Hall and Clarke, Pal. New York, **8**, (1), 1892: 191, pl. 5, figs. 9-14.—Shrock and Malott, Jour. Geol., **41**, 1933: 347.

Hesperorthis tricenaria Schuchert and Cooper, Amer. Jour. Sci. (5), **22**, 1931: 244; Mem. Peabody Mus. Nat. Hist., **4**, (1), 1932: 86, pl. 4, figs. 13, 14, 17, 18-21, 25-27, 29.

Comments.—Schuchert and Cooper (1931) erected the genus *Hesperorthis,* with *Orthis tricenaria,* as described by Hall and Clarke (1892), as the genoholotype; and in a recent monograph (1932) described it in detail.

The Kentland material includes 10 partial and complete dorsal valves, some of which show the exterior and others the interior, and a great many fragments. Not one ventral valve was found in the many slabs which were examined, though a few internal fillings are obscurely preserved in Div. 9. Since the latter are quite convex, in contrast to the flat dorsal valves, it may be that current action, acting on these two types of valves of approximately the same size and weight, but of different area, separated and concentrated flat valves in one place and convex valves in another. That current action was present is apparent from the character and condition of the fossil remains, as has been pointed out above.

The valves found at Kentland agree very closely with the descriptions and figures already published. The median septum-like ridge forming the cardinal process in the shallow notothyrial cavity is quite prominent in the Kentland specimens (Plate 3, Figs. 23, 24). The valves consistently show rounded cardinal edges, the hinge line being somewhat less than the greatest width of the valve, but almost exactly equal to the length. The following measurements (in mm.) show this relation:

Greatest width	14	14	13	12	5.5
Width of hinge line	10	10	10	10	4.5
Length of valve	10	10	10	9.5	4
Number of costae	28	28	28	28	24

As indicated, the Kentland specimens, unless very small, have 28 prominent costae.

Occurrence.—Black River: Iowa, Kentucky, Minnesota, New York, Tennessee, Wisconsin; Canada. Stones River: Tennessee. Kentland, Indiana: Div. 8, along E. wall of McCray quarry; Div. 8 (15), Means and McCray quarries; Div. 9, McCray quarry.

Glyptorthis bellarugosa (Conrad)

Plate 5, Fig. 5

Orthis bellarugosa Conrad, Proc. Nat. Acad. Sci. Philadelphia, **1**, 1843: 333.—Hall, Pal. New York, **1**, 1847: 118, pl. 32, fig. 3.

Glyptorthis bellarugosa Foerste, Bull. Sci. Lab. Denison Univ., **17**, 1914: 258 (Gen. Ref.)—Schuchert and Cooper, Mem. Peabody Mus. Nat. Hist., **4**, (1). 1932: 90, pl. 6, fig. 12.

Comments.—Foerste, in erecting this genus, pointed out the lamellose character of its exterior. Schuchert and Cooper have recently shown the character of the internal structure, and the affinities of this genus to *Orthis* and *Hesperorthis*.

Two fragmental ventral valves from Kentland are referred to this species. All of the important exterior characteristics that can be determined agree closely with published figures and descriptions. The lamellose exterior is very plainly shown.

Occurrence.—Black River: Iowa, Kentucky, Minnesota, Wisconsin; Baffin Land. Chazyan: New York. Kentland, Indiana: Div. 8, W. and N. walls of McCray quarry.

Valcourea deflecta (Conrad)

Plate 4, Fig. 12

Strophomena deflecta Conrad, Proc. Acad. Nat. Sci. Philadelphia, **1**, 1843: 332.

Leptaena deflecta Hall, Pal. New York, **1**, 1847: 113, pl. 31b, fig. 5.

Streptorhynchus deflectum Miller, N. A. Geol. Pal., 1889: 378.

Plaesiomys deflecta Hall and Clarke, Pal. New York, **8**, (1): 1892: 197, 222, pl. 5A, figs. 28-34.

Orthis (Dinorthis) deflecta Winchell and Schuchert, Geol. Minnesota, **3**, 1893: 422, pl. 32, figs. 24-30.

Dinorthis deflecta Grabau and Shimer, N. A. Index Fossils, **1**, 1907: 252, fig. 303a-d.

Valcourea deflecta Schuchert and Cooper, Mem. Peabody Mus. Nat. Hist., **4**, (1): 1932, p. 97, pl. 10, figs. 19, 21, 23.—Shrock and Malott, Jour. Geol., **41**, 1933: 355 (*Valcouria* through typographical error).

Comments.—From the synonymy given above, which is only a general outline, it is obvious that much has been written concerning this species. Recently Schuchert and Cooper have given a very careful analysis of the orthids and have referred the original *S. deflecta* of Conrad to the genus *Valcourea*. Winchell and Schuchert gave a detailed description of the species. The Kentland specimens comprise an internal filling, showing the internal markings of both valves, and several internal impressions of ventral and dorsal valves. They show the internal structures pointed out by Schuchert and Cooper.

Occurrence.—Black River: Illinois, Iowa, Kentucky, Minnesota, Tennessee, Wisconsin. Stones River: Tennessee. Kentland, Indiana: Divs. 4-6, 6-8 along E. wall, McCray quarry.

Pionodema cf. *conradi* (N. H. Winchell)

Orthis conradi N. H. Winchell, 8th Ann. Rep. Geol. Nat. Hist. Surv. Minnesota, 1880: 68.

Orthis (Dalmanella) subaequata conradi Winchell and Schuchert, Geol. Surv. Minnesota, **3**, (1), 1895: 449, pl. 33, figs. 37-39.

Pionodema conradi Cooper, Jour. Paleontology, **4**, 1930: 369-382.

Comments.—Since the group of orthoids regarded in the past as related to *Orthis subaequata* were poorly understood up to the time of Cooper's work in 1930, there would be little of value in quoted descriptions. More can be gained from a study of the type figures and of type localities. The half dozen fragmental shells from Kentland appear not to agree exactly with any of these, but show closest affinities to *P. conradi*, a form from which they differ chiefly in their much larger size. They are scarcely sinuate and are nearly as long as wide. Correctness of generic reference is attested by the well preserved brachiophore processes and supports.

Occurrence.—Kentland, Indiana: Div. 4 6, McCray quarry.

Leptaena charlottae Winchell and Schuchert

Plate 5, Fig. 6

Leptaena charlottae Winchell and Schuchert, Amer. Geol., **9**, 1892: 288; Geol. Minnesota, **3**, 1893: 410, pl. 32, figs. 1-5.

Comments.—A fairly well preserved dorsal valve from Kentland is referred to this species. It shows the internal structure of the valve and agrees closely with the specimen of Winchell and Schuchert's Fig. 4.

Occurrence.—Black River (Decorah): Minnesota. Kentland, Indiana: Div. 8, S.W. Corner of McCray quarry.

Rafinesquina minnesotensis (N. H. Winchell)

Plate 4, Fig. 15

Strophomena deltoidea Owen (not Conrad), Geol. Expl. Iowa, Wisconsin, and Illinois, 1844, pl. 16, fig. 8; pl. 17, fig. 6.

Strophomena minnesotensis N. H. Winchell, 9th Ann. Rept. Geol. Nat. Hist. Surv. Minnesota, 1881: 120.

Rafinesquina minnesotensis Hall and Clarke, Pal. New York, **8**, (1), 1892: 283.—Foerstė, Denison Univ. Bull., Jour. Sci. Lab., **19**, 1921, p. 278.—Shrock and Malott, Jour. Geol., **41**, 1933, p. 348, 350, 355.

Comments.—This species is abundantly represented in the Kentland fauna by ventral exteriors, and dorsal interiors. The better preserved specimens exhibit the distinguishing features of the species.

Occurrence.—Black River: Iowa, Kentucky, Minnesota, Tennessee, Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

Rafinesquina minnesotensis inquassa (Sardeson)

Plate 4, Fig. 13

Strophomena inquassa Sardeson, Bull. Minnesota Acad. Nat. Sci., **3**, 1892: 334, pl. 5, figs. 22-24.

Rafinesquina minnesotensis var. *inquassa* Winchell and Schuchert, Geol. Minnesota, **3**, 1893: 403, pl. 31, figs. 27, 28.

Comments.—A somewhat weathered dorsal valve showing the internal markings is referred to this species. It almost exactly duplicates Sardeson's Fig. 22.

Occurrence.—Black River (Decorah): Minnesota, Wisconsin. Kentland, Indiana: Div. 8, N. wall of McCray quarry, in shaley beds.

Rafinesquina cf. *hermitagensis* Bassler

Rafinesquina hermitagensis Bassler, Tenn. Dep. Ed., Bull. **38**, 1932: pl. 12, figs. 5, 6; Jour. Wash. Acad. Sci., **25**, 1935: 406.

Comments.—Bassler figured without description two valves, apparently both ventral, of a shell to which he gave the name of *R. hermitagensis*. Later he described it briefly. Because of the brief characterization of the species and the poor preservation of the Kentland specimens, we only tentatively refer some of the "Glass Rock" shells (from the northwestern part of the McCray quarry) to this species. Certainly they resemble *R. hermitagensis* more closely than they do any other described species.

Occurrence.—Kentland, Indiana: Div. 8, Means and McCray quarries.

Rafinesquina sp.

Comments.—In the Platteville of Wisconsin and in equivalent strata at Kentland, Indiana, there occurs frequently a small shell that has generally been referred to, in faunal lists, as *Rafinesquina alternata*. Although belonging to the flat-shelled group of the genus rather than to the geniculate-shelled *R. minnesotensis* group, our shell is still far from *R. alternata*. The largest individuals approach 2 cm. in width and 1.5 cm. in height. The shell has an extremely low convexity, the depth of the ventral valves being less than 2 mm. The ventral muscular area is weakly defined. In the dorsal valve the cardinal process is minute and bifid. The crural lamellae are short, weak, and directed laterally to make a low angle with the cardinal margin. Muscle scars and septa are inconspicuous. This species, and several others from the Middle Ordovician of the Upper Mississippi Valley region, await description.

Occurrence.—Lower Blue and the Upper Buff beds of the Platteville formation of Wisconsin, and probably elsewhere. Kentland, Indiana: Div. 4-6, McCray quarry. (Specimens in Geological Museum, University of Wisconsin.)

The Stratigraphic Range of the several specimens of Strophomena in the Platteville and "Decorah" formations of the Upper Mississippi Valley

Because of confusing lateral changes in lithology and numerous so-called faunal recurrences, the Stones River and Black River strata of the Upper Mississippi region do not yield readily to consistent zonal subdivision. For some time, the junior author has believed that the various species of *Strophomena* might be used as guide fossils for the recognition, over relatively wide areas and despite rather far-reaching lithological changes, of the half-dozen faunal zones which constitute this sequence. So long, however, as most of the forms were thrown together as *Strophomena incurvata* (Shepard) their usefulness was ignored. C. L. Fenton,[16] however, described 7 new species, relegated

16 Fenton, C. L., "Forms of Strophomena from Black River and Richmond Formations." Amer. Midland Nat. **11**, 1928: 144-159.

S. incurvata and *S. filitexta* to oblivion (so far as the Mississippi Valley is concerned), and put the genus in a usable condition.

The writers wish to present a brief statement of the range of Fenton's species in the Wisconsin section, since the correlation of some of the faunal zones at Kentland with those in Wisconsin is materially affected by these fossils. There appear to be two stocks of *Strophomena* in Wisconsin—one typified by *S. winchelli* (Plate 4, Fig. 10); the other by such forms as *S. plattinensis* and *S. musculosa* (Plate 4, Figs. 1-2, 4, 11, 14). These two stocks commonly occur side by side, but rarely are two species of a single stock found in the same bed.

The Lower Buff Beds, typically developed in the Rock River Valley of southern Wisconsin, contain *S. plattinensis* as their most abundant fossil. *S. winchelli* occurs in more moderate numbers.

The succeeding Blue Beds, of wide areal distribution, contain in abundance a variety of *S. plattinensis* characterized by a dorsal valve of low convexity, which merits the varietal designation *crassa* here proposed by Raasch (See Plate 4, Figs. 3, 7). In these same beds *S. winchelli* reaches its maximum abundance but is still subordinate in numbers to the *plattinensis* forms. A few shells, which apparently are not conspecific with the two forms just mentioned and which appear to be undescribed, are so uncommon as to be of little stratigraphic value.

The Upper Buff Beds, typically developed in the Beloit area and westward in Green and Dane counties, contain what appears to be a variety of *S. auburnensis*. It differs from the typical species in its greater convexity of both valves and in the marked impression of the vascular sinuses in the mesial region, between the muscular area and the intramarginal ridge. The varietal term *impressa* is proposed by the junior author (See Plate 4, Figs. 6, 8). *S. winchelli* occurs in fair numbers particularly in the lower strata of the sequence.

The lower beds of the Spechts Ferry division contain abundant shells which appear to agree in all respects with *S. auburnensis*. Less common is a shell which, from its general shape and sharp median septum in the muscular area, appears to agree with the rather inadequately described and figured *S. trentonensis* Winchell and Schuchert. In the upper beds of this division the two shells just mentioned occur in moderate and approximately equal numbers.

The Guttenberg-Ion sequence is characterized by numbers of the attractive, highly convex *S. musculosa* (Plate 4, Figs. 11, 14). Associated in moderate abundance are shells as yet undistinguished from the *S. trentonensis* of the underlying Spechts Ferry. It is highly probable that *S. trentonensis*, if properly discriminated by us, is a continuation of the *S. winchelli* stock.

Anomalous rare occurrences of what appears to be *S. plattinensis* in the Upper Buff Beds may represent "throw backs" from the dominant form of the zone, *S. auburnensis* var. *impressa*, or may be a bonafide recurrence. In any case, the occurrence is so rare as to be of no serious stratigraphic significance.

Strophomena plattinensis Fenton

Plate 4, Figs. 1-2, 4; Plate 5, Figs. 1-4

Strophomena filitexta Hall and Clarke, Pal. New York, **8**, (1) 1892: pl. 9, fig. 3; perhaps fig. 5.

Strophomena incurvata Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Strophomena plattinensis Fenton, Amer. Midl. Nat., **11**, 1928: 149, pl. 10, figs. 7-9.

Comments.—This species appears to be the dominant *Strophomena* of the Lower Buff beds of the Platteville formation of Wisconsin, and is a characteristic form in Division 4-6 of the McCray quarry at Kentland, Indiana.

Occurrence.—Platteville of Wisconsin and Plattin of Missouri. Kentland, Indiana: Div. 4-6, McCray quarry.

Strophomena auburnensis Fenton

Plate 4, Fig. 9

Strophomena auburnensis Fenton, Amer. Midl. Nat., **11**, 1928: 148, pl. 9, figs. 1-3, 5.

Comments.—A *Strophomena* from the brown dolomite exposed in the east wall of the McCray quarry differs from the Missouri material described by Fenton in being smaller and only moderately rugose. It compares exactly with the younger two-thirds of the Missouri form, however, and has the characteristic ventral muscle scars of the latter species. Wisconsin shells, agreeing with the typical species in size, are nevertheless rugose. The possibility of the latter character being a local environmental variation must be borne in mind.

Occurrence.—Auburn of Missouri; Spechts Ferry division of the "Decorah" of the Upper Mississippi Valley; and a distinct variety of this species, referred to in another part of this paper, is found in the Upper Buff Beds of the Platteville formation of Wisconsin. Kentland, Indiana: Div. 6-8, E. wall of McCray quarry.

Strophomena trentonensis Winchell and Schuchert

Strophomena trentonensis Winchell and Schuchert, Geol. Minnesota, **3**, (2): 1897, 389, pl. 30, fig. 41.—Foerste, Denison Univ. Bull., Jour. Sci. Lab., **19**, 1921: 278.

Comments.—To judge by the meager description and illustration, this species is characterized particularly by the short, transverse muscular area, which is bisected by a sharp median septum. Shells from Wisconsin, obtained from horizons equivalent to those in Minnesota which contain *S. trentonensis*, were used in identifying the Kentland specimens, with which they coincide closely.

Occurrence.—Spechts Ferry (*Rhinidictya* beds) and Guttenberg-Ion zones of the "Decorah" formation of the Upper Mississippi Valley. Kentland, Indiana: Div. 8 (22) and 9 ("Glass Rock") of the McCray quarry, where young shells predominate.

Rhynchotrema minnesotense (Sardeson)
Plate 4, Fig. 5

Rhynchonella minnesotensis Sardeson, Bull. Minnesota Acad. Nat. Sci., **3**, 1892: 333, pl. 4, figs. 21-23.

Rhynchotrema minnesotense Schuchert, Proc. U. S. Nat. Mus., **32**, 1900: 158.—Shrock and Malott, Jour. Geol. **41**, 1933: 348-355.

Comments.—Three specimens are referred to this species. One rather obese specimen closely compares with figures 20-23 of Winchell and Schuchert (Geol. Minnesota, 3, pt. 1, 1885-1892, pl. 34), and the second is similar to their figures 18 and 19.

Occurrence.—Black River (Platteville and Decorah); Minnesota and Wisconsin. Kentland, Indiana: Larger form from Div. 4-6, McCray quarry; smaller from Div. 8, north wall of McCray quarry. A typical form also occurs in Div. 7 (14), Means quarry.

Zygospira recurvirostris (Hall)

Atrypa recurvirostris Hall, Pal. New York **1**, 1847: 140, pl. 33, fig. 5.

Zygospira recurvirostra Chamberlin, Geol. Wisconsin, **1**, 1883: 155, fig.

Zygospira recurvirostris Foerste, Denison Univ. Bull., Jour. Sci. Lab., 1921: 278.—Shrock and Malott, Jour. Geol., **41**, 1933: 346, 348, 358.

Comments.—The Kentland specimens are slightly larger and rounder than the New York forms, but otherwise similar. The former average 6 mm. in length, 6 mm. in width, and 4 mm. in thickness. They are identical with the specimen figured and described by Weller[17] from New Jersey.

Occurrence.—Black River and Trenton: Canada; Iowa, Kentucky, Minnesota, New York and Wisconsin. Kentland, Indiana: Abundant in Div. 8 (15, 17), McKee, Means and McCray quarries.

Zygospira saffordi (Winchell and Schuchert)

Hallina saffordi Winchell and Schuchert, Amer. Geol., **9**, 1892: 292; Geol. Minnesota, **3**(1), 1893: 473, pl. 34, figs. 55-58.

Zygospira saffordi Beecher and Schuchert, Biol. Soc. Washington, **8**, 1893: 71, pl. 10, fig. 22; pl. 11, figs. 13, 13a.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Comments.—This small form, which is very abundant in certain layers of Div. 4 6, in the McCray quarry, is identified on the basis of the internal structure—that of the brachidium—which in most forms is fairly well preserved. The Kentland forms are slightly smaller than those figured by Hall and Clarke, in Pal. New York, 8, pt. 2, p. 151, figs. 139-141 and pl. LXXXIII, figs. 36-38.

Occurrence.—Stones River (Lebanon): Tennessee. Kentland, Indiana: Div. 4-6, McCray quarry.

---

17 Weller, S., "A report on the Paleozoic Paleontology of New Jersey," Geol. Surv. New Jersey, **3**:161, pl. 10, figs. 23-26, 1903.

Echinoderma

CYSTOIDEA

Cystid Plates

Description.—The Cystoidea are represented by isolated asymmetrical polygonal plates, preserved as internal and external molds. The test evidently was thin but strongly sculptured concentrically on the external surface. The plates are fixed along an axis which runs through the minute but acutely elevated apex. Broad shallow furrows, which lie in a plane normal to the plane of the flexure, depress the plate on opposite sides of the apex. The largest plate has a maximum diameter of 8 mm, and a height of less than 2 mm.

Horizon and Locality.—Not uncommon in Div. 4-6, McCray quarry, Kentland, Indiana.

Mollusca

PELECYPODA

Ctenodonta gibberula Salter

Plate 6, Fig. 13

Ctenodonta gibberula Salter, Canadian Org. Rem., dec. **1**, 1857: 38, pl. 8, fig. 6.—Ulrich, Geol. Minn., **3**, (2), 1897: 587, pl. 42, fig. 37; fig. 44 f-g, 599.

Comments.—Ulrich, in the reference cited in the synonymy, gave a detailed description, which disagrees on certain points with Salter's, especially with respect to the depth of the muscle scars. The figures which accompany the two descriptions, however, coincide. The Kentland fauna includes two specimens which show three internal fillings of this well characterized species.

Occurrence.—Stones River: Tennessee. Black River: (Leray) Canada; Illinois, Iowa, Minnesota and Wisconsin. Kentland, Indiana: Divs. 6-8, 9, McCray quarry.

Ctenodonta cf. *levata* (Hall)

Plate 7, Fig. 22

Nucula levata Hall, Pal. New York, **1**, 1847: 150, pl. 34, figs. 1a-i.

Ctenodonta levata Billings, Geol. Canada, Geol. Surv. Canada, 1863: 175, figs. 162a, b.—Shrock and Malott, Jour. Geol., **41**, 1933: 354.

Comments.—Certain Ctenodontas occurring as internal fillings in the dolomite of Divs. 4-6 at Kentland, and in the Platteville dolomite of southern Wisconsin, are identical. They appear to be intermediate, as far as outline is concerned, between *C. albertina* and *C. nitida*. From the former they differ in being considerably shorter posteriorly (the presence or absence of a pit beneath the beak—a diagnostic character in *C. albertina*, could not be determined). They differ from the latter in being longer posteriorly, and in having the beaks directed dorsally and not posteriorly.

Hall's brief characterization is not adequate for close specific discrimination, and his plates are non-commital. More revealing is the statement by Grabau and Shimer (North American Index Fossils, *1*, 1909: 394) that *C. levata* "differs from *C. albertina* in its greater proportional height and convexity, and in the presence of a pit beneath the beak." Ulrich (Geol. Minnesota, *3*, (2), 1897: 599), under the description of *C. filistriata*, remarks that Hall's

Nucula levata is closely related to *C. nitida*. Since our species is intermediate between the two species just mentioned, and since *C. levata* (Hall) is a wide ranging form, the writers provisionally refer the Indiana and Wisconsin forms to that species, at least until they have opportunity to examine suitable comparative material.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. Platteville dolomite ("Blue Beds"), quarry on Chicago and Northwestern railroad, 2 miles west of Klevenville, Dane county, Wisconsin.

Ctenodonta cf. *logani* Salter

Plate 6, Figs. 15-16

Ctenodonta logani Salter, Canadian Organic Rem., dec. **1**, 1859: 36, pl. 8, figs. 3, 3a. —Shrock and Malott, Jour. Geol., **41**, 1933: 354.

Comments.—Ulrich (Geol. Minnesota, *3*, (2), 1897: 591, pl. 42, figs. 26-28) supplements Salter's original description with a more detailed description. He places particular stress on the gibbosity of the valves—a character later emphasized by Salter. The Kentland specimens agree closely with the figures of Salter and Ulrich, but without comparative material it is difficult to determine the amount of convexity shown by authentic examples of the species. The identification of the forms (internal fillings and molds) from Kentland must, therefore, remain provisional at present.

Occurrence.—Platteville (Upper Buff Beds): Wisconsin. Black River: Ontario. Kentland, Indiana: Div. 4-6, McCray quarry.

Ctenodonta ovata robusta (Ulrich)

Plate 6, Figs. 17-18.

Ctenodonta nasuta Ulrich, Geol. Minnesota, **3**, (2), 1897: 584, pl. 42, fig. 30.

Comments.—Under his redescription of Hall's *Tellinomya nasuta*, Ulrich remarks:

> Associated with this species in Wisconsin and at Paquette's Rapids there is a form which, though it has been identified unreservedly with *C. nasuta* by Hall and others, I find to be strictly identical with that species. The anterior end is higher and larger and the posterior end shorter, so that the beaks, instead of being in front of the mid-length, are a trifle behind that point, the muscular impressions are deeper, and the hinge plate is on the whole narrower and much less constricted in the middle. This form, for which I propose the varietal designation *robusta*, was figured by Prof. Hall in the Tenth Annual Report of the Regents of the University of New York on page 183, as *Tellinomya nasuta*. He figures two specimens of which the smaller may belong to *nasuta*. The larger example, however, (figures 1 and 3), I refer to the variety *robusta*, and I do so with the utmost confidence, the specimen being in my possession at this moment. . . .

Hall (Rep. Sup. Geol. Surv. Wisconsin, 1861: 28; specimen figured in 1895 in the Mem. Amer. Mus. Nat. Hist., *1*, (2), 52, pl. 6, fig. 9), described *Tellinomya ovata*, a form doubtless with close genetic relationship to *C. nasuta*, but having the beak nearly central instead of decidedly anterior in position as in the latter form. Since the beaks in Ulrich's *C. nasuta* variety *robusta* are not only subcentral but slightly posterior in position, the writers

believe it should be classed under *ovata* rather than *nasuta*. The illustration of Hall's *T. ovata* was not available to Ulrich at the time he completed his manuscript on the pelecypods of Minnesota.

Occurrence.—Platteville: Beloit, Wisconsin and Leray: Paquette Rapids, Ottawa River, Canada. Kentland, Indiana: Div. 6, E. wall of McCray quarry.

Ctenodonta socialis Ulrich

Plate 6, Fig. 8

Ctenodonta socialis Ulrich, Geol. Minnesota, **3**, (2), 1897: 594, pl. 42, figs. 59, 60.

Comments.—Internal fillings from Kentland agree closely with Ulrich's description and figures, as well as with specimens, doubtless this species, from the Platteville of Wisconsin.

Occurrence.—Platteville: Minnesota and Wisconsin; Trenton: Kentucky. Kentland, Indiana: Div. 4-6, McCray quarry.

Ctenodonta nasuta (Hall)

Ctenodonta nasuta Salter, Canadian Organic Rem., dec. **1**, 1859: 35, pl. 8, figs. 1, 2.—Foerste, Denison Univ. Bull., Jour. Sci. Lab., **19**, 1921: 278.

Comments.—This species was reported from Kentland by Foerste in 1921. He stated that it, along with several other species, was found "in a very fine-grained, brownish-gray limestone having a conchoidal fracture, resembling some phases of the Plattin limestone of eastern Missouri." He does not state from which quarry this rock came, but it seems almost certain that it was collected in the McCray quarry and probably from Div. 4-6. We have not found any specimens referable to the species.

Occurrence.—Black River: Illinois, Indiana, Minnesota, Missouri, New Jersey and Wisconsin; Canada. Kentland, Indiana: probably from Div. 4-6, McCray quarry.

Cyrtodonta billingsi Ulrich

Plate 7, Figs. 10-11, 18, 20-21, 23-24

Cypricardites ventricosus Whitfield (not Hall), Geol. Wisconsin, **4**, 1882: 209, pl. 5, fig. 9.

Cyrtodonta billingsi Ulrich, Geol. Minnesota, **3**, (2), 1897: 538, pl. 40, figs. 2-6.

Comments.—Numerous internal fillings from Kentland coincide closely with Ulrich's description and figures.

Occurrence.—Black River: Illinois, Minnesota, New Jersey and Wisconsin; Decorah: Missouri. Kentland, Indiana: Div. 4-6, McCray quarry.

Cyrtodonta cf. *huronensis* Billings

Plate 6, Fig. 12

Cyrtodonta huronensis Billings, Geol. Surv. Canada, Rep. Progr. for 1857, 1858: 180, figs. 3, 4.—Shrock and Malott, Jour. Geol. **41**, 1933: 354-355.

Comments.—A single internal filling of a right valve seems to agree

closely with *C. huronensis,* as well as with the characters which Ulrich (Geol. Minnesota, *3,* (2), 1897: 536) mentions in his description of *C. subovata*—a species which Bassler (U. S. Nat. Mus., Bull. *92,* (1), 1915: 362) considers conspecific with *C. huronensis.* In view of the sparseness and imperfection of the Kentland material, however, it seems best not to make an unqualified assignment at this time.

Occurrence.—Black River: Canada; Kentucky, Minnesota (Decorah), Tennessee and Virginia (Lowville). Kentland, Indiana: Divs. 4-6 and 8, McCray quarry.

Vanuxemia rotundata (Hall)

Plate 6, Figs. 10-11

Cypricardites rotundata Hall, Rep. Sup. Geol. Surv. Wisconsin, 1861: 29; Geol. Rep. Wisconsin, **1**, 1862: 38, fig. 7; p. 437.

Vanuxemia rotundata Ulrich, Geol. Minnesota, **3**, (2), 1897: 552, pl. 38, figs. 8-14. —Shrock and Malott, Jour. Geol., **41**: 1933, 355.

Comments.—Hall's types were figured by Whitfield (Mem. Am. Mus. Nat. Hist., *1,* 1903: 53, pl. 6, figs. 13-16). Many specimens preserved as internal fillings at Kentland agree in all details with the description, illustrations, and representative specimens of this species—one which is common in the Platteville of Wisconsin.

Occurrence.—Black River (Platteville): Minnesota and Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

Vanuxemia decipiens kentlandensis Raasch var. nov.

Plate 6, Figs. 4-6, 9

Vanuxemia decipiens Ulrich, Geol. Minnesota, **3**, (2), 1897: 562, pl. 39, figs. 1-5.

Description.—The following is the original description of *V. decipiens:*

Shell rather small, strongly convex, highest posteriorly, the length of a large specimen 23 mm., its height 18 mm. Hinge line straight, two-thirds as long as the shell, terminating subangularly behind, rounded in front; posterior margin slightly oblique, strongly rounded and somewhat prominent in the lower half; basal line moderately narrowly rounded, very short, the greater part of it occupied by the muscular scar. Beaks of moderate size and fullness, incurved, the anterior half slightly flattened in the casts. This flattening, which is produced by the unusual internal thickening of the anterior part of the shell, extends obliquely backward and downward from the beaks toward the middle of the ventral edge. Anterior muscular scar somewhat uniform, not as sharply defined below as is usual for the genus; very distinct, however, and partly overlapped above by the filling of the beaks. Pallial line sharp in the anterior two-fifths, obscure behind. Posterior muscular impression too light to be determined with certainty. Hinge plate narrow, with two slender horizontal posterior lateral teeth in the left valve and three in the right. Cardinal teeth unknown.

Comments.—Several internal fillings from Kentland coincide in most particulars with the above description. They average considerably larger, however, than those from Minnesota, ranging between 28 mm. and 32 mm. in the specimens studied. Furthermore, the hinge rounds very gradually into the posterior margin in our form; and so far as may be judged by comparison with the rather unsatisfactory illustrations of the typical form, the Kentland speci-

mens have shorter lateral teeth, situated so far back that they curve in conformity with the rounding of the hinge line into the posterior margin. It is not unlikely that comparison with the types would show our specimens to have decidedly less convexity. The cardinal teeth, not observed in the Minnesota specimens, are well preserved in one specimen from Kentland. These number 3 in each valve, are rather short and heavy, and are moderately inclined from the horizontal.

It is probable that direct comparison of the Kentland specimens with the types would reveal sufficient dissimilarity to warrant separation of them as a distinct species, but on the basis of Ulrich's figures and description, it seems best to designate these somewhat different forms as a variety of *V. decipiens*, using the name *kentlandensis*.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 506, Geological Museum, University of Wisconsin.)

Vanuxemia sulcata Raasch sp. nov.

Plate 6, Fig. 7

Vanuxemia n. sp. (cf. *niota* Hall), Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—A single well preserved internal filling of a left valve, and the corresponding external mold, show decided affinities with the half dozen species and varieties which Ulrich (Geol. Minnesota, *3*, (2), 1897: 558, *et. seq.)* groups around *V. hayniana*. Considering the close similarity of those forms, it is regrettable that still another species must be erected. The Kentland form, however, shows distinct differences from all those forms discussed by Ulrich.

V. subrotundata, close to our shell in general outline, lacks the umbonal ridge and furrow. *V. abrupta* has decidedly more terminal beaks, and likewise lacks the ridge. *V. nana* has distinct differences in outline, particularly the anterior, which is more rounded and extends farther forward. *V. gibbosa*, which has never been figured, nevertheless can be excluded readily because of the terminal position of the beaks. *V. cardinata*, likewise never figured, can certainly be eliminated on account of "the ligamental area which is at least twice as high as in adult examples of Safford's species *V. hayniana*." He mentions further a small variety of *V. gibbosa* (as yet undescribed), which is obviously not to be considered as conspecific with our form.

There remains the typical *hayniana*. There are extant two good illustrations of the interior of that species, both of right valves. The first appeared in Safford's "Geology of Tennessee" in 1869, and was excellently reproduced by Bassler (Tenn. Dep. Ed. Div. Geol., 1932). The second illustration ,by Ulrich, appeared in 1897 (Geol. Minnesota, *3*, (2) 1897: pl. 40, fig. 20). There are marked differences between the two illustrations, especially in the nature and position of the lateral teeth, which in Safford's form are such as to make it evident that the Kentland shell is not closely related. Ulrich's form, if properly reproduced, is by no means conspecific with Safford's, but closely resembles the Kentland shell. Since no described species appears to coincide with our form, it seems best to figure and describe it as a new species,

which is characterized particularly by a subcircular outline, with the beak about one-fourth the length of the hinge-line from the anterior-dorsal end; by 3 short lateral teeth obliquely truncating the anterior-ventral corner; and by the well marked umbonal ridge and sulcus.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 507, Geological Museum, University of Wisconsin.)

Ambonychia cf. *attenuata* Hall

Plate 6, Fig. 1-2

Ambonychia attenuata Hall, Rep. Sup. Geol. Surv. Wisconsin, 1861: 33.

non *Ambonychia attenuata* Whitfield, Geol. Wisconsin, **4**, 1882: 206, pl. 5, fig. 6.

non *Clionychia lamellosa* Ulrich, Geol. Minnesota, **3**, (2), 1897: 495 (erroneous change of specific and generic reference).

Ambonychia attenuata Whitfield, Mem. Am. Mus. Nat. Hist., 1, 1903, 59, pl. 7, figs. 8-11 (figures Hall's types).

Clionychia lamellosa Bassler (pars), U. S. Nat. Mus., Bull. **92**, (1), 1915: 241.

Description (Hall).—Shell elongate-ovate, widest below the middle; width a little more than two-thirds the length; attenuate at the beaks; ventricose in the middle, regularly arcuate from the beak to the base; hinge line straight, a little more than one-third as long as the greatest length of the shell, and very oblique to the axis. Beaks elevated and directed forward, obtusely pointed and incurved at their extremity. Surface character unknown, expect a few undefined concentric undulations upon the casts.

Comments.—Hall's description, which was not accompanied by illustrations, failed to mention the presence or absence of the subrostral lobe—a feature which has since assumed importance as a generic character. In 1882 Whitfield published a figure of a specimen from Wisconsin. With respect to Hall's description and Whitfield's figure, Ulrich in 1897 stated:

> The form of this species seems to be quite variable, but after a careful study of numerous specimens I have concluded that much of this supposed instability is due to distortion through pressure. On the other hand, for the same reason, I found it utterly impossible to detect really normal specific differences between the specimens which Hall in his original work and Whitfield in the later volume cited above [Geol. Wisconsin, **4**] have separated as two species under the names *Ambonychia lamellosa* and *A. attenuata*. According to my view the latter is founded upon specimens of the former whose original form has changed by pressure acting so as to decrease the diagonal or the vertical diameter of the valves, causing them to appear abnormally elongate. Whitfield's figure of *A. attenuata* (op. cit., plate V, fig. 6) represents instead of the left, most surely the right side of an obviously distorted specimen.

Subsequent to Ulrich's remarks, Whitfield in 1903 published figures of Hall's types, *A. attenuata* among others. His figures 8 and 9, flat and profile views of the holotype (which it automatically becomes since it is the first figured specimen; the specimen shown in figures 10 and 11 must then rank as a paratype), clearly show a prominent subrostral lobe, the presence of which, according to Ulrich (Geol. Minnesota, *3*, (2), 1897: 292) is, in the internal filling, one of the diagnostic characters separating *Ambonychia* from his genus *Clionychia*. If the type specimen of Hall's *Ambonychia attenuata* is truly an *Ambonychia*, which is certainly the case, it can scarcely be conspecific with *Clionychia lamellosa*, the genotype of Ulrich's genus.

In view of the above, there can remain no doubt that *Ambonychia atten-*

uata is a valid species, although the specimen figured by Whitfield in the Wisconsin publication might easily be *Clionychia lamellosa*. The identity of his specimen has no bearing upon this question.

Two imperfect internal fillings of right and left valves show close similarity to *A. lamellosa*. In view of the fragmentary character of the material, however, it seems best not to make a definite assignment.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry.

Clionychia triangularis Raasch sp. nov.
Plate 6, Fig. 3

Clionychia n. sp. Shrock and Malott, Jour. Geol., **41**, 1933: 354.

Description.—In outline the valves of this species approximate *C. lamellosa*, but differ particularly in the proportionately shorter hinge line, and the resultant subrhomboidal shape. It differs distinctly from that species, further, in its greater convexity, its markedly incurved beaks, and in the possession of concentric undulations paralleling the growth lines as in *C. undulata* (Emmons). Its relations to the latter appear to be close, but Emmon's shell is decidedly wider than high, while in the Kentland form the height somewhat exceeds the width.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 508, Geological Museum, University of Wisconsin.)

Lyrodesma cf. *acuminatum* Ulrich
Plate 6, Fig. 14

Lyrodesma acuminatum Ulrich, Geol. Minnesota, **3**, (2), 1897: 609, pl. 42, figs. 1-5.

Comments.—In a poorly preserved internal filling from Kentland, all the characters retained indicate close relationship of the specimen with *L. acuminatum* Ulrich. Better material must be obtained, however, before a reliable specific designation can be given.

Occurrence.—Black River (Decorah): Minnesota. Kentland, Indiana: Div. 9, McCray quarry.

Modiolopsis sp.

Comments.—Several internal fillings of a small species of this genus seem to be conspecific with shells, apparently undescribed, from the Platteville of Wisconsin. The dorsal and ventral margins are sub-parallel; the anterior extension of the shell is very limited and bears a well-defined muscle scar; the mesial sulcus is broad and shallow; and the largest individual does not exceed 6 mm. in length.

Occurrence.—Platteville: Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

GASTROPODA

Tetranota wisconsinensis (Whitfield)
Plate 8, Figs. 1-3

Bellerophon Wisconsinensis Whitfield, Ann. Rep. Geol. Surv. Wisconsin, 1878: 76; Geol. Surv. Wisconsin, **4**, 1882: 223, pl. 6, figs. 15, 16.

Tetranota wisconsinensis Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 881, pl. 65, figs. 26-29.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Comments.—A large series of internal fillings and external molds in the Kentland material agree closely with the essential points in the descriptions of the species and with the figured specimens. Our material furnishes no additional data on the species.

Occurrence.—Black River (Platteville): Minnesota and Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

Salpingostoma buelli (Whitfield)

Plate 8, Fig. 4

Bucania buelli Whitfield, Ann. Rept. Geol. Surv. Wisconsin for 1877, 1878: 76.

Bucania (Tremanotus?) buelli Whitfield, Geol. Wisconsin, **4**, 1882: 224, pl. 6, figs. 12-14.

Bucania halli Shrock and Malott, Jour. Geol., **41**, 1933: 354.

Salpingostoma buelli Whiteaves, Pal. Foss., **3**, (3), Geol. Surv. Canada, 1897: 189.—Ulrich and Scofield, Geol. Minnesota, **3** (2), 1897: 900, pl. 47, figs. 34-37.

Comments.—A single fragment of the outer volution of an internal filling is at hand from Kentland. The posterior end of the dorsal slit is preserved on the fragmentary specimen, leaving no doubt as to the generic reference. In surface sculpture and general form the specimen agrees exactly with numerous specimens available from the Platteville of Wisconsin.

Occurrence.—Platteville (Upper Buff and Blue Beds): Upper Mississippi Valley. Kentland, Indiana: Div. 4-6, McCray quarry.

Phragmolites grandis (Ulrich)

Plate 8, Figs. 6-8

Conradella grandis Ulrich, Geol. Minnesota, **3**, (2), 1897: 908. pl. 62, fig. 67; pl. 67, figs. 16-18.

Phragmolites grandis Bassler, U. S. Nat. Mus., Bull. **92**, (2), 1915: 972.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—This species is closely related to *C. triangularis* but reaches a much greater size, the greatest diameter of one of the specimens being fully 30 mm. Then the transverse section of the whorls, which also increase more rapidly in size, is a little different, the dorsal slopes being more convex, the sides less angular, and the transverse diameter relatively greater, the latter exceeding the vertical diameter by one-sixth, whereas the two dimensions are equal, or the hight the greater, in *C. triangularis*. Furthermore, the folds of the surface imbrications are fewer in number, there are only five or six on each of the dorsal slopes to eight or nine in that species. Then the revolving ridges are more distinct, and the keel is more abrupt, especially on interior casts of *C. grandis*, the latter exhibiting distinctly a broad furrow on each side of the keel. The slit extends quite half around the last whorl.

Comments.—Abundant external and internal molds and fillings at Kentland show most of the characters of the species just described. A possible exception is the nature of the cross-section of the whorl. Some of the Kentland specimens present a section more closely resembling that which Ulrich and Scofield have figured for *P. fimbriatus* but others agree quite closely with that of *P. grandis*. The former type of section was noted on whorls

obviously not of maximum (or adult) size, and this fact may have some bearing on the descent of *P. grandis* in accordance with the concept of recapitulation. Otherwise the Kentland specimens agree closely with *P. grandis* as to maximum size, number and nature of imbricating folds, character of the revolving ridges and their preservation on the internal mold as well as the extent of the peripheral slit.

Occurrence.—Stones River (Lebanon): Tennessee. Kentland, Indiana: Div. 4-6, McCray quarry.

Raphistomina cf. *modesta* Ulrich

Plate 8, Fig. 5

Raphistomina modesta Ulrich, Geol. Minnesota, **3**, (2), 1897: 943, pl. 68, figs. 14-17.

Description.—Differs from *R. lapicida*, which it resembles more closely than any other known, in being smaller (12 to 15 mm. in diameter), in having a proportionally smaller umbilicus, and in its surface markings. On the upper side, which is also a little more depressed, the lines of growth are very faint, while the peripheral edge turns rather distinctly upward. On the lower side the lines of growth are likewise obscure except in the peripheral half of the last whorl, where they appear as rather coarse undulations of which the best specimen has about seven in 5 mm. The course of the lines of this side, which of course corresponds with the outline of the lower lip, is more convex anteriorly than in *R. lapicida*. . . . *R. denticulata* is a larger shell, has a higher spire and deeper sutures.

Comments.—Remains of a single specimen are at hand from Kentland. They consist of a well preserved internal filling and a small chip preserving a part of the external mold of the periphery and of the last whorl. The umbilical side of the shell was not observed, because in order to study it, it would be necessary to damage the specimen. Most of the characters which Ulrich has listed were observed in the Kentland specimen, namely: size, 13 mm.; relatively depressed spire; faint lines of growth; upward reflection of the peripheral edge; and very shallow sutures. The under side of the shells could not of course be compared.

There is, however, one and there may be two important differences between Ulrich's description and the material at hand. The peripheral edge, as shown in the internal mold, is minutely denticulated as in *R. denticulata* (which, however, has a higher spire and a deeper suture). Ulrich's figure seems to show a somewhat more elevated spire for *R. modesta* than is attained by the Kentland specimen, which (to judge from the pen sketches of *R. rugata)* has an elevation approximating the one of that species. The shell of the latter, however, has a very different contour with respect to the upper surface of the whorls (nearly flat instead of being convex near the suture and concave near the periphery as in *R. modesta)*, and has much stronger surface markings.

Whether the denticulated margin has been overlooked in *R. modesta* or whether, on the other hand, the umbilical view would display further differences between the Kentland shell and that species, must await study of additional material. If the Kentland specimen is not *R. modesta* it is apparently a new species, and if such ultimately turns out to be the case, the species name *R. kentlandensis* is suggested for it.

Occurrence.—Stones River (Murfreesboro): Tennessee. Kentland, Indiana: Div. 4-6, McCray quarry.

Omospira cf. *alexandra* (Billings)

Murchisonia ventricosa Salter (not Hall, 1847), Can. Org. Rem., Geol. Surv. Canada, dec. **1**, 1859: 23; pl. 5, figs. 2, 2a, 3.

Murchisonia alexandra Billings, Geol. Surv. Canada, Pal. Foss., **1**, 1865: 172.

Omospira alexandra Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 946, pl. 70, figs. 66-67.

Description (Billings).—Shell rather large, turbinate, acutely conical; apical angle from 45 degrees to 50 degrees; whorls about six, strongly ventricose, with a flat band in the upper third. The aperture appears to be large and ovate; the inner lip is thin and folded over so as to conceal the minute umbilicus. Surface finely striated. Length about 30 lines; width of body whorl about 15 lines.

Ulrich and Scofield add:

This species has the same general characteristics as the preceding *O. laticincta*, yet may be distinguished at once by its more depressed and more rounded volutions. Its apical angle also is narrower, being between 40 degrees and 45 degrees, while the aperture is more rounded. There is not a sign of an umbilical perforation.

Comments.—A single, poorly preserved filling of an external mold occurs in the material from Kentland. It is clearly referable to *Omospira*, on the basis of its "elongate turbinate" shape, its obtuse, shoulder-like angulation (looking like the peripheral band of the *Pleurotomariidae*), and the course of the growth lines "which first curve strongly backward in their course from the suture" but which, in the band-like space above the angulation, "are turned in the opposite direction." These characteristics result in a shell having the general appearance of the low-spired forms of *Hormotoma*, but the shell may be distinguished readily by the high position of the band-like space upon the whorls, and by the much more gentle backward flexure of the growth lines. Were the aperture preserved, much more fundamental distinctions might be discerned.

As to the specific reference, the writers are less confident. Approximately the second to the fifth volutions are present, so that either we are dealing with an immature shell, or the later volutions have been broken away. Hence, it is difficult to compare with *O. alexandra*, the described species which it most closely resembles, since the younger volutions, in the only figured specimens of that species, are absent. It possibly differs from that species in having a somewhat wider space between the band and the suture.

Occurrence.—Black River: Kentucky; (Leray), Canada. Kentland, Indiana: Div. 6, McCray quarry.

Lophospira conradana Ulrich and Scofield

Plate 8, Fig. 9

Lophospira conradana Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 979, pl. pl. 72, figs. 29-32.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Comments.—One well preserved external mold and internal filling and several fragmentary internal fillings are included in the Kentland material.

These agree with the illustrations and descriptions of the Minnesota specimens, especially with respect to the general proportions, the increasing angularity of the whorls, the ventricose basal whorl, the shoulder-like prominence below the suture, the strong concavity between the shoulder and the peripheral carina, and the distinctly lamellose nature of the growth lines and their strong retral curve.

Occurrence.—Black River (Platteville): Minnesota and Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

Lophospira oweni kentlandensis Raasch var. nov.

Plate 8, Figs. 10-11

Lophospira oweni Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 980, pl. 73, figs. 41-45.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—Hight, of Black River specimens, 25 to 36 mm., ... apical angle 59 degrees to 62 degrees. Volutions six to seven, the first very minute, decidedly angular. Peripheral band prominent, thick and rounded, sometimes margined by a delicate line on each side. Upper slope concave, except near the suture where there is usually a broad, rounded ridge or carina; this ridge, however, becomes quite obsolete on the sixth or seventh volution. Lower side sloping inward, scarcely ventricose, the outline being first concave, next convex, then straight or concave and finally convex again, there being a peculiar swelling just behind the minute umbilicus. The first convexity beneath the peripheral band represents the lower carina of *L. perangulata* and other species, and in young shells it is sharp enough to be called a carina, but as growth proceeds it becomes more and more obtuse. Aperture straight at the inner margin, and somewhat narrowly produced at the lower angle. Surface markings rarely preserved; whenever preserved they consist of rather distant, delicate, sublamellose striae, with very fine lines between them, all curving backward strongly to the peripheral band.

Discussion.—Numerous well preserved fillings and molds from the "mollusk bed" at Kentland have a much more acute apical angle than the typical *oweni*, which they resemble more closely than they do any other described form. In the older (apical) portion of the spire, much of the whorl below the slit band is exposed. In typical *oweni*, on the other hand, the suture lies quite high on the whorl in the older half of the shell but drops decidedly in the later half which is identical in the typical and the varietal forms. In short, a telescoping of the higher whorls of variety *kentlandensis* would produce typical *oweni*. There can be little doubt that the variety is a forerunner of the somewhat later typical form, since the two shells agree in all details except the apical angle.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 509, Geological Museum, University of Wisconsin.)

Lophospira perangulata (Hall)

Murchisonia perangulata Hall, Pal. New York, **1**, 1847: 41, pl. 10, fig. 4 (not p. 179, pl. 38, figs. 7a, b).

Lophospira perangulata Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 972, pl. 63, figs. 1-7.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—Ulrich and Scofield gave a redescription of the species based on more than 100 specimens:

Shell small, hight 10 to 20 mm.; apical angle usually about 52 degrees, but varying between 50° and 57°. Volutions about six, the last inclining to become free, scarcely ventricose below, very gently concave above; peripheral band prominent, sharp, trilineate; the lower carina distinct though not very prominent, sometimes very obscure on casts of the interior; upper slope without a carina, the gentle concavity extending to the suture. A small abruptly defined umbilicus always present. Mouth subtriangular, slightly drawn out below. Surface markings consist of two sets of strongly recurved lines of growth, one distant and sub-lamellose, the other much finer and closely arranged between the former.

Comments.—A single external mold from the Kentland locality has growth lines indicating the v-shaped notch of the *perangulata* section of the genus. The upper slope of the whorls is very gently concave, with no upper carina. The peripheral carina is sharply trilineate. Two sets of growth lines occur as described above in Ulrich and Scofield's description.

A peculiarity of the Kentland specimen is the periodic coalescence of the lower and median ridges of the peripheral band on the fifth whorl to produce the effect of a series of nodes. Only two of these are visible in the small section of the shell represented by the mold, and hence it is not possible to determine whether this is a constant specific character or merely a pathological condition.

Occurrence.—Black River: (Auburn), Missouri, Kentucky, Minnesota, New York, Tennessee, Virginia; (Lowville), Canada. Stones River: Tennessee. Chazyan: New York. Kentland, Indiana: Div. 4-6, McCray quarry.

Lophospira serrulata (Salter)

Plate 8, Fig. 12

Murchisonia tricarinata Hall, Pal. New York, **1**, 1847: 178, pl. 38, fig. 6c (not 6a, b).
Murchisonia serrulata Salter, Geol. Surv. Canada, dec. **1**, 1859: 20, pl. 4, fig. 1.

Lophospira serrulata Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 968, pl. 72, figs. 51-55; pl. 73, fig. 57.—Shrock and Malott, Jour. Geol. **14**, 1933: 355.

Description.—Both Hall's and Salter's descriptions are based upon unsatisfactory material, resulting in an unsatisfactory characterization of the species. Ulrich and Scofield give a long and detailed description based on a series of well preserved specimens. Their concluding remarks characterize this striking species:

> *L. serrulata* is the only species of the genus known to us having the flangelike peripheral keel serrated on the edge like a circular saw. It is an excellent specific character. . . . In fully grown individuals the last whorl descends very rapidly and becomes widely separated from the preceding one; . . . .

Comments.—Fragmentary remains of 10 individuals have been collected from two different faunal horizons at Kentland. The external molds are characterized by the serrate periphery; the internal fillings, by the marked uncoiling of the last whorl.

Occurrence.—Black River: Minnesota, Wisconsin (Platteville), Illinois, Tennessee, Virginia; Canada. Kentland, Indiana: Div. 4-6, and (Div. 6 or 8 along E. wall), McCray quarry.

Lophospira sexlineata Raasch sp. nov.

Plate 8, Fig. 13

Description.—This species is based upon four external molds, including the type. The lines of growth, showing only the very slightest backward inclination in their course to the peripheral keel, place this species in the *bicinta* section of the genus, while the fine, regular, sharply elevated, and closely arranged condition of these growth lines confines it to the *L. bicinta* subsection. In general contour, however, it presents a very different appearance from other species of that sub-section, exhibiting in fact a Gyronemoid aspect, which extends to both the outline of the whorls and the distribution of the carinae.

Height of largest individual about 10 mm.; apical angle as shown in the illustration. Volutions 6, regularly increasing, rounded, ventricose below, with a (relatively) very flat base due to the marked underturnings of the slope of the whorl below the lower carina. The peripheral band is wide, not strongly convex, and conspicuously trilineate, with the lines remarkably distinct. The sharp upper carina forms the angulations dividing the upper half of the whorl into a flat, gently sloping shoulderlike upper third, and a flat, steeply sloping lower two-thirds. Uncoiling of the last whorl reveals an additional carina produced by the sharp angulation between the shoulder and the inner slope of the whorl. The lower slope of the whorl is divided by the lower carina into a flat, steeply sloping upper half and a gently convex, and strongly underturned lower slope. The lower carina on the older whorls is concealed by the suture, but is exposed on the fifth as well as the final whorl.

As in most species of *Lophospira*, there is a considerable thickening of the inner lip. The aperture, judging from a single mold, appears to be nearly circular, and the apertural notch, to be very shallow. Umbilicus wanting or extremely minute.

In addition to the very finely and regularly sculptured growth lines and the six carinal lines, the whorls are ornamented by periodic swellings and depressions 1.5 to 2 mm. apart.

The name *sexlineata* is applied to this species because of the 6 conspicuous and nearly equally elevated lines produced by the upper and lower carinae, the trilineate peripheral carina, and the angulation between the shoulder and the inner slope of the whorl.

Comments.—The writers know of no *Lophospira* which closely resembles the one under discussion. *L. fillmorensis* from the Trenton (Galena) of Minnesota differs, among other things, in the narrowness of the peripheral band and the marked concavity of the upper slope below the shoulder. *L. (Seelyia?) lirata* which most nearly approaches our form in the general character of the whorls, if it be truly referable to *Lophospira*, apparently belongs to the *perangulata* section of the genus and hence is not comparable.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 510, Geological Museum, University of Wisconsin.)

Liospira progne (Billings)

Pleurotomaria progne Billings, Canadian Nat. Geol., **5**, 1860: 163, fig. 6.

Liospira progne Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 996, pl. 48, figs. 38-44.

Description (Ulrich and Scofield).—Width 25 to 35 mm.; height about half the width; volutions four to four and a half; apical angle about 120°.

This is another of the forms that, especially where it occurs as casts of the interior, is generally referred to as *Raphistoma lenticular* = *Liospira americana* Billings sp. Although casts of the interior resemble that species very closely. . . . the affinities of *L. progne* are really much nearer *L. micula* Hall sp. . . . .The closed umbilicus distinguishes both very easily from *L. americana*, *L. vitruvia*, and other species of the genus having an open umbilicus, while the extreme faintness of their suture lines and the flatness or slight convexity of the upper surface of their volutions separates them at once from such close allies as *L. helena* Billings sp. and *L. persimils* Ulrich.

Comments.—This brief description (Billing's original description unfortunately is not available to us), is sufficient to characterize the species and leave no doubt as to the correct reference of the Kentland specimen. The closed umbilicus, with a distinct umbilical concavity, plus the "extreme faintness of their suture lines and the flatness or slight convexity of the upper surface of . . . volutions," plus of course the general contour of the shell distinguish *L. progne* from all species of *Liospira* except *L. micula*, which does not exceed 16 mm. in diameter. The Kentland specimen is nearer 25 mm. The peripheral band of our specimen is distinctly convex and inconspicuous.

Occurrence.—Stones River—Trenton: (Stones River and Black River), Kentucky, Minnesota, Tennessee, etc.; (Trenton), Canada. Kentland, Indiana: Div. 4-6, McCray quarry.

Liospira obtusa Ulrich and Scofield

Plate 8, Figs. 14-16

Liospira obtusa Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 997, pl. 68, figs. 30-34.

Description.—"Hight of a large specimen 25 mm., width of same 44 mm.; hight of a small example 17 mm., width of same 32 mm. Volutions four to five, with the periphery rounded and the upper side very slightly convex. Umbilical cavity rather large in casts but in the shell itself it is filled, excepting a minute central perforation, by a distinctly outlined, thick external deposit on the inner side of the whorls. This deposit is as heavy relatively on the inner whorls as on the last. The last feature, together with the obtuse character of the periphery, disinguishes this species from *L. angustata*."

Comments.—Many internal fillings and external molds from Divs. 4-6 show all the essential characters of this species. They agree with the Ulrich and Scofield's description, especially in the nature of the umbilical perforation, and the outline of whorls in the internal filling. The proximal half of the whorl is decidedly convex. The peripheral half is in fact flat, but the elevation of the rather wide peripheral band produces the effect of concavity in this portion. The suture is a delicate, sharply depressed line which does not interrupt the general contour of the shell.

Occurrence.—Black River (Platteville): Illinois, Minnesota, Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

Liospira vitruvia (Billings)

Pleurotomaria vitruvia Billings, Pal. Foss., **1**, Geol. Surv. Canada, 1865: 171.
Liospira vitruvia Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 995, pl. 69, figs. 3-8.

Comments.—Only 2 fragmentary specimens are at hand from the Kentland locality. These, however, show both the open character of the umbilicus and its angular margin, a combination of characters which is shared by no other described species. The slightly concave upper side of the whorls is an added feature which distinguishes these specimens from the abundant associated form, *L. obtusa*.

Occurrence.—Black River—Richmond: Iowa, Kentucky, Minnesota, New York, Ohio, Tennessee, Wisconsin; (Black River), Canada. Kentland, Indiana: Div. 4-6, McCray quarry.

Liospira sp.

Comments.—An external mold of the upper side of a small low-spired form (13 mm.), with flat whorls and very shallow and faintly marked sutures, occurs in dolomite from an isolated fault block along the east wall of the McCray quarry. This specimen is unlike any of the species of *Liospira* discussed above, but does not permit specific reference.

Liospira sp.

Plate 8, Fig. 17.

Description.—A large *Liospira* from the McCray quarry because of its poor preservation, can not be identified specifically. The specimen is the internal filling of a low-spired form, with slightly over 2 complete whorls preserved. The greatest width of the shell is 4 cm. and its height originally does not appear to have been much more than 1 cm.

Occurrence.—Div. 7 (14), McCray quarry.

Eotomaria trochoides Raasch sp. nov.

Plate 8, Figs. 18-19

Eotomaria cf. *labiosa* Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—This description is based on a good internal filling and external mold, and a second more shattered example. Width 15 mm., height 14 mm., apical angle, as shown in Figs. 18-19, Plate 8, increasing from the apex to the final whorl due to the increased spreading of the successive whorls; volutions 6.

Shell conical with concave sides, base nearly flat, umbilicus small with limits well defined, sutures distinct but not deep. Band concave, sharply defined, its lower edge forming the periphery of the whorl. The internal filling shows no trace of the band. The later whorls have their upper surfaces gently concave, sloping off to the nearly vertical band. Under surface flat in earlier whorls but concave in the final whorl; curving shortly and sharply to the umbilicus. Much of the aperture is broken or concealed in the

specimens, but apparently it was subrhomboid, with a certain amount of reflection of the inner lip. Lower lip and apertural notch about as in *E. canalifera*. Surface markings very fine, consisting of growth lines, barely preserved on the lower surface; not observed on the upper which, however, bears a suggestion of extremely fine revolving lines. The direction of the growth lines, as far as can be discerned, parallels the contour of the lower lip.

The *Trochus*-like outline of the shell, with its conical spire and flat base, suggests the specific name. In outline, the shell differs widely from any known *Eotomaria,* and approaches *Euconia,* a Beekmantown genus. Its other characters, however, agree essentially with the description of the genotype, *Eotomaria canalifera*. The large umbilicus, more regularly conical outline, and the more obscurely defined band are characters which bar the species from *Euconia*. In spite of its rather low stratigraphic occurrence, the Kentland shell does not represent an intermediate stage between *Eotomaria* and *Euconia,* and the coincidence of general outline between it and the latter genus probably has no significance. This negative assumption is based upon the typically Eotomarian nature of all other features of our shell.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 511, Geological Museum, University of Wisconsin.)

Clathrospira subconica (Hall)

Plate 8, Figs. 20-21

Pleurotomaria subconica Hall, Pal. New York, **1**, 1847: 174, pl. 37, figs. 8a-e; 304, pl. 83, figs. 3a-e.

Clathrospira subconica Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 1006, pl. 69, figs. 47-50; pl. 70, figs. 5-6.—Shrock and Malott, Jour. Geol., **41**, 1933: 354.

Comments.—This species occurs at Kentland as internal fillings and external molds, which agree in all details with the description of Ulrich and Scofield. In surface sculpture they most closely match the Tennessee "Glade Limestone" form, which has the revolving lines "wanting entirely on the inner side." The specimens clearly preserve the several features which are diagnostic in distinguishing between *C. subconica* and *C. conica*. These include larger size, concavo-convex instead of uniformly flat upper surface of the whorls, and the absence of the concave space beneath the peripheral band.

Occurrence.—Black River—Richmond: Iowa, Minnesota, Ohio, Tennessee; Anticosti, Canada; (Trenton), New York. Kentland, Indiana: Div. 4-6, McCray quarry.

Hormotoma gracilis angustata (Hall)

Murchisonia ? angustata Hall, Pal. New York, **1**, 1847: 41, pl. 10, figs. 2a, b.

Hormotoma gracilis var. *angustata* Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 1015, pl. 70, figs. 30-36.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Comments.—Ulrich and Scofield state:

"Has more uniformly rounded whorls and slightly wider band than the typical form. So far as observed, this variety never reaches a length of 25 mm., the majority of the specimens varying between 17 and 20 mm."

A single fragmentary specimen showing an internal filling and external mold is at hand from Kentland. All discernible characters agree with the available description and figures of *H. gracilis angustata.*

Occurrence.—Black River: Kentucky, Minnesota, New York, Tennessee, Virginia, and Wisconsin. Kentland, Indiana: Div. 4 6, McCray quarry.

Ophiletina sublaxa Ulrich and Scofield

Plate 7, Fig. 1

Ophiletina sublaxa Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 1030, pl. 74, figs. 40-42 and 47.

Comments.—In the Kentland material is a single external mold of the upper side of an average-sized shell, sufficiently well preserved to permit identification. The specimen agrees more closely with the typical form than with the variety *depressa,* especially in the contour of the inner surface of the whorls. The distinction between the present species and *O. angularis,* the other described species of the genus, is so obvious that it is not necessary to justify, in detail, the assignment of the Kentland specimen to the former species.

Occurrence.—Black River (Platteville): Illinois, Minnesota, Wisconsin. Kentland, Indiana: Div. 6 or 8, E. wall McCray quarry.

Eccyliopterus sp. nov., aff. **E. beloitensis** Ulrich and Scofield

Plate 7, Figs. 2-3

Comments.—This genus is represented at Kentland by a single specimen, showing an external mold and internal filling with the concave side of the shell visible. It closely resembles *E. beloitensis,* but differs in having a much steeper slope on the upper side of the whorl between the top of the collar and the margin. The whorls, however, seem to expand somewhat less rapidly than do those of that species.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry.

Eccyliomphalus undulatus Hall

Plate 7, Fig. 4

Ecculiomphalus undulatus Hall, Rep. Geol. Surv. Wisconsin, 1861: 37.—Whitfield, Mem. Am. Mus. Nat. Hist., **1**, (2), 1895: 63, pl. 8, figs. 1-3 (figures Hall's types).

Eccyliomphalus undulatus Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 1036, pl. 75, figs. 19-23.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Comments.—A single, nearly complete internal filling closely matches Hall's description. The groove below the center along the ventral (inner) side mentioned in his description is well preserved.

Occurrence.—Black River (Platteville): Illinois, Minnesota, Wisconsin. (Stones River): Tennessee. Kentland, Indiana: Div. 4-6, McCray quarry.

Trochonema cf. *umbilicatum* (Hall)

Pleurotomaria umbilicata Hall, Pal. New York, **1**, 1847: 43, pl. 10, figs. 9a-h; 175, pl. 38, figs. 1a-g.

Trochonema umbilicata Salter, Geol. Surv. Canada, Can. Org. Rem., dec. **1**, 1859: 27, pl. 6, fig. 3.

Discussion.—A mold of the spire of a *Trochonema* with a relatively great apical angle might prove to be this species, but final identification must await satisfactory material.

Occurrence.—Black River and Trenton: Illinois, Iowa, Kentucky, Minnesota, New York; Canada. Kentland, Indiana: Div. 6 or 8, E. wall McCray quarry.

Holopea ampla Ulrich and Scofield

Plate 7, Figs. 5-6

Holopea similis Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Holopea ampla Ulrich and Scofield, Geol. Minnesota, **3**, (2), 1897: 1065, pl. 79, figs. 22-25.

Comments.—Specimens which appear to be young shells of this species are not uncommon at Kentland.

Occurrence.—Platteville Formation of the Upper Mississippi Valley. Kentland, Indiana: Div. 4-6, McCray quarry.

Stenotheca kentlandensis Raasch sp. nov.

Plate 7, Figs. 7-9, 12-13

Stenotheca sp. Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—Three well preserved internal fillings and external molds have been collected at Kentland. The smallest has a maximum diameter of 9 mm. and a height of 6.5 mm.; the largest has a diameter of 17.5 mm. and a height of about 14 mm. The base is somewhat asymmetrical and the direction of greatest diameter a matter of chance. The curvature of the shell is such that the beak, in internal fillings, nearly but not quite overhangs the margin of the shell. The greatest elevation of the shell occurs just behind the beak, posterior to which it rounds off gradually to the distal margin. Fairly distinct transverse growth lines are observable on the external molds, one of which also shows extremely faint radiating striae. Muscle scars are not preserved.

The Kentland specimens bear a general resemblance to *S. extensa* of the "Stones River Group" of the upper Mississippi Valley, and if the latter is correctly referred to the genus, then the present species also belongs there. The Kentland forms differ markedly from *S. extensa*, however, especially in amount of curvature and distinctness of the radiating striae.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 512, Geological Museum, University of Wisconsin.)

Hyolithes baconi Whitfield

Plate 7, Figs. 14-15

Hyolithes baconi Whitfield, Ann. Rep. for 1877, Wisconsin Geol. Surv., 1878: 77; Geol. Wisconsin, **4**, 1882: 225, pl. 6, figs. 9-11.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—Shell of moderate size, measuring from one to one and a half inches in length, with a diameter at the aperture from one-fourth to one-third of the length. Dorsal side of the shell depressed convex, more abruptly rounded near the margins and on the edges, the surface marked by transverse striae which arch gently forward and are parallel to margin of the dorsal extension; dorsal projection regularly rounded and one-third as long as the width of the aperture. Ventral surface about twice as deep as the dorsal, strongly subangular along the middle and the surface marked by transverse striae which are directed nearly straight across the shell. Transverse section of the tube subtriangular or triangularly elliptical.

Comments.—Several shells from the Molluscan Zone compare exactly with the description, the figures, and with numerous specimens from Wisconsin in the University of Wisconsin collection. To Whitfield's description we may add that the shell is uniformly thin except near the apex where a comparison of external mold and internal filling indicates that the shell substance is greatly thickened; in fact that the cavity ceases several millimeters from the extremity. (This observation was made on Wisconsin specimens.)

We also figure (from Kentland) an operculum, a structure not figured for *H. baconi*.

Occurrence.—Black River (Platteville): Minnesota, Wisconsin. Kentland, Indiana: Div. 4-6 (and Div. 6 or 8, E. wall), McCray quarry.

Salterella billingsi Safford

Plate 7, Figs. 16-17

Salterella billingsi Safford, Geol. Tennessee, 1869: 289.
Salterella billingsi Bassler, Tenn. Dep. Ed., Div. Geol., Bull. **38**, 1932: pl. 4, figs. 32-33.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—From one and a half to two inches long, straight, large end of longest specimens about one-sixth of an inch in diameter, tapering to a point, striated longitudinally, cross-section circular. A beautiful and abundant species; at least three cones, one within the other.

Comments.—Kentland shells agree closely with Bassler's figures except in size, ours averaging about one-third smaller. As remarked elsewhere, there is a tendency for the mollusks from Kentland to be below normal size. The delicately fluted sculpture of the surface is usually destroyed by the coarse crystallization of the dolomite in which the molds are preserved. A few specimens, however, show it clearly.

Occurrence.—Stones River (Murfreesboro): Tennessee. Kentland, Indiana: Div. 4-6, McCray quarry.

Pterotheca expansa (Emmons)

Plate 5, Figs. 8, 9, 13

Delthyris expansus Emmons, Geol. New York, **2**, 1842: 397, fig. 2, figs. 109-112.
Clioderma expansa Hall, **14**th Rep. New York State Cab. Nat. Hist. 1861: 98.

Pterotheca expansa Lesley, Geol. Surv. Pennsylvania, Rep. P. **4**, 1889: 821, fig.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—Emmons figured the original specimen of *P. expansa* but did not describe it. Hall (p. 96) gave the following description of the genus *Clioderma,* in which he included numerous species of *Pterotheca.*

Shells more or less arcuate, somewhat calyptraeform, subtriangular or oval, with the apex marginal and incurved in the same plane, not known to be convolute, carinate upon the back, abruptly and broadly expanding, with the anterior margin sinuate; interior concave, much wider than deep. A concave shelly partition covers the posterior half or more of the cavity. Substance of the shell of moderate thickness, lamellose, with surface lamellose-striate parallel to the exterior margins or lines of growth.

Though *P. expansa* has been figured many times, there seems to be no complete description of the species. This may be due in large part to the fragmental condition of most specimens. Fairly well preserved shells, from both Kentland and numerous localities in Wisconsin permit the following remarks:

The shell is subelliptical, having a width averaging 42 mm. and a length, from back to anterior margin, of about 32 mm. The back is distinctly carinate, with the carina produced beyond the anterior margin of the shell, giving a sinuate appearance in an interior view. The carina is acute and rises from 2-5 mm. above the somewhat convex exterior surface. The interior of the shell is concave, and is considerably wider than deep. A shell partition or septum occupies the posterior half or more of the internal cavity. It is triangular, having its apex at the beak of the shell, its sides attached to the shell and its anterior edge free. The pointed part of the plate is attached under the beak to the shell by means of two short vertical plates. The septum is slightly concave generally. The angle included between its lateral edges varies between 78 degrees and 82 degrees, and is fairly constant in the dozen specimens before us. All specimens examined show only fillings and molds of the exterior and interior. The position of the septum is indicated on the filling of the interior by a broad, shallow, triangular depression, extending anteriorly from the beak. Some specimens preserve a filling of the internal cavity. In this there are 3 tooth-like projections near the beak, a very conspicuous one in the middle representing the posterior extension or the continuation of the carina, and the two less conspicuous lateral ones representing the fillings between the vertical plates by which the septum is fastened, and the shell proper. (Plate 5, Fig. 13.) The lateral edges of the septum are attached to the shell along a line roughly parallel with the lateral edges of the shell proper, and from 7-9 mm. inward from the shell margin. The anterior margin of the septum appears to have ended at a slightly greater distance from the anterior margin of the shell.

The angle made by the lateral edges of the septum, the distance from the anterior and lateral margins of the shell to the anterior lateral edges of the septum, the distance the septum reaches into the cavity, the general outline of the shell, and the convexity of the carinate exterior surface are the features which are of most value in the identification of this form.

Occurrence.—Black River: Illinois, Missouri, New York and (Platteville), Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

Pterotheca intermedia Shrock sp. nov.

Plate 5, Figs. 10-12

Pterotheca attenuata Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—One well preserved specimen shows the impression of the internal septum, and a filling of the cavity. When complete, it was approximately 40-44 mm. wide and 30 mm. long, having about the same dimensions as *P. expansa*. The angle between the lateral edges of the septum is 67 degrees, as compared to some 80 degrees in *P. expansa* and *P. saffordi*, and is exactly the same as in *P. attenuata*, as figured by Hall (Rep. Geol. Surv. Wisconsin, 1, 1862: 40, Fig. 3). The Kentland form is distinctly different from the last-named species, however, in having a broad area between the line of attachment of the septum and the margin of the shell. This area is at least 10 mm. wide in our form, and may be even wider, whereas it is barely 5 mm. in *P. attenuata*. (See Plate 5, Fig. 7). Hence, the Kentland shell has a subelliptical, not a triangular outline. Possessing features which are found in *attenuata, expansa* and *saffordi*, the new species may well be designated *intermedia*.

Occurrence.—Kentland, Indiana: Div. 4-6 (and Div. 6 or 8 along E. wall), McCray quarry. Also found in the Platteville formation of Wisconsin, several miles north of New Glarus, Green County, where it is associated with *P. expansa*. (Holotype, No. 513, Geological Museum, University of Wisconsin.)

CEPHALOPODA

"Orthoceras" cf. *sociale* Hall

Plate 9, Fig. 7

Orthoceras gregarium Hall (not Sowerby, 1839), Rep. Supt. Geol. Surv. Wisconsin, 1861: 46.

Orthoceras sociale Hall, Miller, N. Amer. Pal. Foss., 2d ed., 1877: 245.—Clarke, Geol. Minnesota, **3**, (2), 1897: 789, pl. 55, fig. 7.

Comments.—So little has been published regarding the smaller Ordovician orthoceratites that the writers hesitate to attempt even a provisional reference of the Kentland shells of this type. Since, however, a remarkably complete and well-preserved shell is included in the Kentland fauna, notice of it must be included.

Clarke stated, concerning *O. sociale*, "There are also a few examples from the Trenton and Galena horizons at Cannon Falls which bear very much the same proportions, symmetrical form, and general aspect of *O. sociale* and hence suggest the presence of that species in these rocks." If this suggestion proves true, then *O. sociale* would be added to such long ranging forms as *Hormotoma gracilis* and *Liospira vitruvia*, which persist with or without minor variations through half or two-thirds of a system.

The Kentland specimen, compared with examples of *O. sociale* from the Richmond of Graf, Iowa, differs chiefly in its much smaller size. Our specimen is 54 mm. long and when complete probably did not exceed 65 mm. Incomplete shells from Graf commonly exceed 100 mm. Otherwise it agrees,

as far as can be ascertained from available material, with the details of *O. sociale*, including the presence of rather distant longitudinal striae on the inside of the shell.

As Foerste has pointed out, the generic designation *Orthoceras* has been so restricted that only a few American forms are retained, and *O. sociale* is not among these. Until further studies permit the reference of this species and that from Kentland to an authentic genus, the writers consider it advisable to employ the old name *Orthoceras* in its broader sense, realizing that the Kentland specimen is not a true representative of that genus.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry.

Spyroceras cylindratum Foerste

Plate 7, Fig. 19

Orthoceras arcuoliratum Hall, Pal. New York, **1**, 1847: 198, pl. 42, figs. 7b, c (not 7a).

Spyroceras cylindratum Foerste, Denison Univ. Bull., Jour Sci. Lab., **27**, 1932: 97, pl. 11, figs. 3A-B; 6A-B; 7A-C.

Comments.—A single external mold of a portion of the shell 6 cms. in length is our only specimen from Kentland. The distinct flexed annulations with narrow crests and wide, flattish troughs; the general proportions of the shell; and the faint vertical lines are the basis for identifying our specimen with *S. cylindratum*.

Occurrence.—Black River (Leray): Quebec. Trenton: New York. Kentland, Indiana: Div. 6 or 8, McCray quarry.

Kionoceras kentlandense (Kindle and Breger)

Plate 9, Fig. 1

Orthoceras (Kionoceras) kentlandensis Kindle and Breger, **28**th Ann. Rep. Dep. Geol. Nat. Res. Indiana, 1904: 470, pl. 21, fig. 2.

Kionoceras kentlandense Foerste, Denison Univ. Bull., Jour. Sci. Lab., 19, 1921: 277.

Description.—Shell a longicone, small, sides straight, slowly tapering. Section slightly oval (due to pressure?); septa distant, almost flat; siphon large, eccentric. The depth of the chambers is more than half the width of the shell, except near the body chamber, where a few septa become crowded. Surface marked by longitudinal ribs which are quite faint in the cast.

This species is known from a single cast now in the Indiana State Museum (No. 685), which has a length of 78 mm., width at upper end 11 mm., at lower end 7 mm. At the lower extremity there are seven chambers in 32 mm., but just below the body chamber there are only five compartments in 9 mm. Twelve mm. above the base of the body chamber is a raised line, origin unknown.

This form can be recognized by its very distant septa. From *Orth. jolietensis* of Meek and Worthen, this species may be distinguished by the absence in the former of the longitudinal ridges, and the shallowness of the septa in the latter. Our species is also a much smaller shell.

Rare. Kentland.

Comments.—The above description is taken *verbatim* from the original

description, and the figure is a photostat copy of the one accompanying the description.

Foerste redescribed the species as follows:

Type.—The specimen enlarges from 7 mm. at the lower end to 11 mm. at the upper end, the interval being 78 mm., suggesting an apical angle of 3 degrees. Only the cast of the interior of the conch is at hand. This is marked by 22 or 23 vertical ribs which are distinct, though low, along the entire length of the specimen, including the living chamber. At the top of the phragmocone there is a series of 6 camerae successively shorter in length, indicating that the specimen had attained maturity; all 6 of these camerae occupy a total length equal to only ten-ninths of the diameter of the conch. Of the living chamber a length of 17 mm. remains, but this does not include the upper part of the living chamber which, in this genus, should show a contraction along the upper part of the cast of the interior, a short distance below the aperture. The siphuncle is about 1.25 mm. in diameter at the base of the specimen and its location is somewhat eccentric. No trace of the surface markings, beyond the presence of vertical ribs, is present in this type.

Locality and Horizon.—The type is numbered 685 in the State Museum of Indiana, at Indianapolis, Indiana. It occurs in a very fine-grained, brownish-gray limestone having a conchoidal fracture resembling some phases of the Plattin limestone of eastern Missouri. The same limestone, at Kentland, Indiana, contains *Columnaria halli, Rafinesquina minnesotensis, Strophomena trentonensis, Zygospira recurvirostris, Ctenodonta nasuta, Actinoceras beloitense, Isotelus* cf. *platycephalus,* and *Thaleops ovatus.* This is a typical representative of that fauna in the upper Mississippi Valley which is correlated with the Black River limestone of New York.

Occurrence.—Probably from Div. 4-6 or 8, McCray quarry. (Holotype, No. 685, State Museum of Indiana, Indianapolis.)

Actinoceras beloitense (Whitfield)

Orthoceras (Actinoceras) Beloitense Whitfield, Ann. Rep. Geol. Surv. Wisconsin, for **1877**, 1878: 77; Geol. Wisconsin, **4**, 1882: 226, pl. 8, fig. 1; pl. 10, figs. 9, 10.

Actinoceras beloitense Clarke, Geol. Minnesota, **3**, (2), 1897: 782, pl. 47, fig. 19.—Foerste, Denison University Bull., Jour. Sci. Lab., **19**, 1921: 278.

Comments.—Foerste and Teichert[18] in a recent paper gave a detailed discussion of the species, and Foerste[19] reported it from Kentland, with some other Black River fossils.

Occurrence.—Black River (Platteville): Wisconsin. Thessalon Island, Lake Huron. Arctic America. Kentland, Indiana: Probably from Divs. 4-6 or 8, McCray quarry.

Whitfieldoceras Foerste

Whitfieldoceras mumiaforme (Whitfield)

Plate 9, Figs. 5, 6

Oncoceras mumiaforme Whitfield, Ann. Rep. Geol. Surv. Wisconsin for **1879** (1880), p. 58; Geol. Wisconsin, **4**, 1882: 232, pl. 7, figs. 3-5.

Clinoceras mumiaforme Hyatt, Proc. Boston Soc. Nat. Hist., **22**, 1884: 282; Clarke, Geol. Minnesota, **2**, (2), 1897: pl. 57, figs. 7, 10.

---

18 Foerste, A. F., and Teichert, C., "The Actinoceroids of East-central North America," Denison Univ. Bull., Jour. Sci. Lab., **25**: 228-231, plates, 1930.

19 Foerste, A. F., "Notes on Arctic Ordovician and Silurian cephalopods," Denison Univ. Bull., Jour. Sci. Lab., **19**: 278, 1921.

Whitfieldoceras mumiaforme Foerste, Denison Univ. Bull., Jour. Sci. Lab., **28**, (2), 1933: 60; **27**, (1), 1932: pl. 32, figs. 1A-C; 2A-B; 3; 4.

Comments.—A small section of the lower part of a shell, preserved partly as an internal filling, and partly as an external mold, is included in the Kentland fauna. Despite its fragmentary character, it may be referred to *Whitfieldoceras mumiaforme* on the basis of the type of curvature of the shell; the size of the "air chambers"; the rather abrupt increase in diameter of the latest preserved chambers, following a series of successive chambers which show almost no enlargement; the small, centrally located siphuncular perforation; and the extremely fine, undulatory, concentric surface sculpture. The specimen seems to indicate a much smaller size than is normal for the Wisconsin and Minnesota forms. Many of the other mollusks, however, from the same horizon as the *W. mumiaforme* specimen, also are smaller than normal.

Occurrence.—Black River (Platteville): Wisconsin. Kentland, Indiana: Div. 4-6, McCray quarry.

Poterioceras kentlandense Rowley

Plate 9, Figs. 8, 9

Poterioceras kentlandensis Rowley, Contrib. to Ind. Pal., **2**, (1), 1906: 3, pl. 3, figs. 1-2.—Shrock and Malott, Jour. Geol., **41**, 1933: 346.

Description.—Shell large, straight and strangely fish-like in shape, being compressed latterly [laterally].

Cross section rather strongly elliptical.

The type specimen preserves but little of the body chamber, but enough to show a gradual forward contraction to the aperture.

The greatest diameter of the specimen is at the rear end of the body chamber, whence backward the contraction is so gradual as to give a rather elongate form to the fossil.

The septa are simple and in the specimen figured, about half an inch apart, noticeably curving as they cross the sides, the convexity being toward the rear.

Siphon subcentral, lying much nearer one of the long sides of the ellipse (short diameter) than the other, the position on the diameter being toward the rear.

On the long diameter the siphon is half way. There is a gradual lessening in size of the siphon from the back of the specimen toward the front, that would apparently make the tube rather small where it leaves the body chamber. The surface of the shell has been entirely removed.

The amount of ellipticity in the cross section of the shell in the longer and shorter diameters is nearly two to one (just back of the body chamber 4 inches to 2½, while at the rear end 2 1-16 to 2½ inches).

Length of the type specimen ten inches.

While the siphon is rather strongly moniliform, our shell differs in some respects from typical Poterioceras, the cross section being elliptical instead of circular and with an outline hardly fusiform, while the length is greater than in typical species.

The horizon of this fossil is Lower Silurian [Ordovician] (G. K. Greene). Locality, McKee's quarry, three and half miles south-east of Kentland, Sec. 25, Tp. 27 N., R. 9 West, Newton county, Indiana. (Rowley).

Comments.—The type was once in G. K. Greene's collection, but its present location is not known.

Occurrence.—Kentland, Indiana: Div. 8, McKee quarry. (Holotype, present location unknown).

Kentlandoceras shrocki Foerste

Plate 9, Figs. 2-3

Kentlandoceras schrocki Foerste, Denison Univ. Bull., Jour. Sci. Lab., **28**, 1933: 73; **27**, 1932: pl. 7, figs. 2A-B.—Shrock and Malott, Jour. Geol., **41**, 1933: 355.

Description.—Holotype 10 mm. long, the living chamber occupying 7 mm. of this length, while the 4 camerae still attached to this chamber occupy a combined length of 3 mm. The convex ventral outline of the conch has a radius of curvature of about 25 mm. Its lateral diameter enlarges from 4.5 mm. at its base to 5.1 mm. at the base of the living chamber, and to 7 mm. at its aperture. Its cross-section is circular. The sutures of the septa rise slightly in a ventral direction. The siphuncle is narrowly exposed along the median line of each of the upper 3 camerae. Its diameter here is estimated at 0.5 mm., the exact diameter being unknown.

Occurrence.—Kentland, in northwestern Indiana; in the Black River dolomite. Collected by Robert R. Shrock *(sic.)*

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype, No. 87116, U. S. National Museum.)

Tripteroceras indianense Raasch sp. nov.

Plate 9, Fig. 4

Tript[*er*]*oceras* n. sp. Shrock and Malott, Jour. Geol. **41**, 1933: 355.

Description.—The reference of this apparently undescribed species to the genus *Tripteroceras* is tenable only if Whitfield's *Cyrtoceras planodorsatum* is truly a member of that genus. The Kentland species is clearly congeneric with the latter form, but in general contour of the shell is even more aberrant, when compared with the genotype, *Orthoceras hastatum* Billings, than is *T. planodorsatum*. Two specimens are at hand, both molds in dolomite representing the mature part of the shell.

The habitation chamber, in the larger individual, has a length of 12 mm., a dorso-ventral diameter at its widest part of 9.5 mm., and a lateral diameter of about 10 mm. The greatest lateral diameter occurs at the ventral third of the chamber. The minute siphuncular perforation of the septa lies 1 mm. from the flat ventral surface and 4 mm. from the highly convex dorsal surface. Sides convex, less so than the dorsal surface, and rounding rather gradually to the ventral surface. Septa have a rather gentle inclination toward the aperture dorsally. They are gently convex with a broad and shallow ventral lobe. Depth of first "air-chamber" 1.5 mm. as compared with a width of 6 mm.

The second specimen is a small shell, probably less than 3 cm. in length when complete, with a much more abrupt taper than *T. planodorsatum*. The sides diverge regularly to the aperture, with a slightly arcuate outline dorsally. The surface sculpture consists of extremely fine and closely spaced transverse reticulate ornamentation.

Occurrence.—Kentland, Indiana: Div. 4-6, McCray quarry. (Holotype No. 514, Geological Museum, University of Wisconsin.)

Arthropoda

TRILOBITA

Bathyurus spiniger (Hall)
Plate 10, Fig. 14

Acidaspis spiniger Hall, Pal. New York, **1**, 1847: 241, pl. 64, fig. 5.
Bathyurus spiniger Clarke, Geol. Minnesota, **3**, (2), 1897: 723, figs. 38-40.

Comments.—An almost complete cranidium is referred to this species The entire glabella is covered with fairly closely spaced, rather prominent pustules and tubercles, the larger ones being near the posterior margin. The occipital ring is also covered with similar tubercles, but the large central spine has been broken off. The Kentland specimen is almost a duplicate of Clarke's (Fig. 38). A small pygidium with the prominent spine present was found in Div. 8, McCray quarry.

Occurrence.—Black River: Quebec; Illinois, Iowa, Kentucky, Missouri, New York, etc. Kentland, Indiana: Div. 8, N. wall and NW. corner, McCray quarry.

Isotelus gigas DeKay
Plate 10, Figs. 11-13

Isotelus gigas DeKay, Ann. Lyceum Nat. Hist. New York, **1**, 1824: 176, pl. 12, fig. 1; pl. 13, fig. 1.—Shrock and Malott, Jour. Geol., **41**, 1993: 355, 356.

Comments.—The Kentland material referred to this species, which according to Raymond[20] probably represents several distinct species, consists of 6 pygidia, 2 fragmental cephalons, 1 hypostoma and several free cheeks. The pygidia resemble those figured from Black River strata throughout the United States. The axial ridge is usually obscure and without observable segmentation. The dorsal furrows are obscure.

Occurrence.—Mohawkian and Cincinnatian: United States and Canada. Kentland, Indiana: Divs. 4-6 and 8, McCray quarry; and Div. 8, Means quarry.

Bumastus milleri (Billings)
Plate 10, Figs. 4 A-C

Illaenus milleri Billings, Can. Nat. and Geol., **4**, 1859: 375, fig. 10.
Bumastus milleri Raymond and Narraway, Ann. Carnegie Mus., **4**, 1908: 249, pl. 61, figs. 9-10; pl. 62, figs. 3-5.—Shrock and Malott, Jour. Geol., **41**, 1933: 347.

Description.—Oblong, oval, indistinctly trilobed, length one or two inches, width variable, about two-thirds the length, proportional length of head thorax and pygidium about as 6, 4½, 5½.

Head transversely semioval, evenly convex somewhat abruptly elevated in the front half and more depressed behind, not trilobed, genal angles rounded, eyes moderately large, lunate, less than half their length from the posterior borders, about their own length from the genal angle, and full six eights the entire width of the head from each other. Cheeks rather small, facial suture cutting the front margin a little within the parallel of the eye and the posterior margin just behind the outside of the eye. The dorsal furrows are represented by two obscure not always visible indentations each about one line in width, situated at about one-fourth the length of the head from

20 Raymond, P. E., Bull. Mus. Comp. Zool., **58**:247-263, 1914.

the posterior margin with a distance between them about equal to half the distance between the eyes. These pits are visible on the cast of the interior of the head and constitute a good character for distinguishing it from other species. . . .

Comments.—This small trilobite is represented in the Kentland fauna by 2 glabellae, and a specimen, containing an entire pygidium and 8 or 9 thoracic segments, slightly enrolled.

Both cephalons are moderately convex, have the eye lobes far apart, and show well-developed lunate depressions about half-way between the eye lobe and the median line. No other markings are visible. Measurements are:

Width 14 and 15 mm. Length 11 and 12 mm. Height 3 and 4 mm.

They agree closely with Clarke's (Minn. Geol. Surv. *3*, (2), 1897: 720) Fig. 33, to which Raymond has shown the name *Bumastus milleri* should be applied, as well as with Billings's original figure.

The pygidium is badly worn but still its outline is subelliptical and somewhat narrower than the wider portion of the thorax.

Measurements: Pygidium: width 14 mm.; length 9 mm.

9 Thoracic segments—17 mm. wide at widest point.

Occurrence.—Black River: New Jersey, New York; Ontario, etc., Kentland, Indiana: Div. 7 (14), Means quarry.

Thaleops ovatus Conrad

Plate 10, Figs. 2A-E

Thaleops ovata Conrad, Proc. Acad. Nat. Sci., Philadelphia, **1**, 1843: 332.—Clarke, Geol. Minnesota, **3**, (2), 1897: 716, figs. 25-28.

Thaleops (Illaenus) ovatus Hall, Pal. New York, **1**, 1847: 259, pl. 67, figs. 6a-b; 318, pl. 67, fig. 6c.

Thaleops ovatus Foerste, Denison Univ. Bull., Jour. Sci. Lab., **19**, 1921: 278.—Shrock and Malott, Jour. Geol. **41**, 1933: 355.

Comments.—The Kentland specimens referred to this species consist of three incomplete cranidia and one fairly well preserved pygidium, which agree fairly closely with published figures and descriptions. One fragmental cranidium (Plate 10, Fig. 2B) shows unusually well the spine produced by the lateral extension of the genal angle. The pygidium, possessing an obscurely segmented axial lobe, is identical with Clarke's figures.

Occurrence.—Black River: Illinois, (Platteville), Minnesota, Wisconsin; Ontario. Kentland, Indiana: Div. 5, 4-6 and 6, McCray quarry.

Ceraurus bispinosus Raymond and Barton

Plate 10, Fig. 10

Ceraurus bispinosus Raymond and Barton, Bull. Mus. Comp. Zool., **54**, 1913: 536, pl. 1, figs. 3-4.

Description.—The cephalon is roughly semicircular, and about 0.45 as long as broad. The glabella is very convex, expanding forward and reaching the frontal margin. The expansion is about 1 mm. in 4. The frontal lobe and the first part of glabellar lobes are much more convex than the posterior ones and compose about two-thirds of the glabella. There are three pairs of glabellar furrows; of these, only the posterior pair are deeply incised. There is further a slight constriction running backward from the inner end of each of these two furrows to the neck-furrow. The fixed

cheeks are very convex, highest at the eye, and are separated from the glabella by deep dorsal furrows. The free cheeks are apparently small. The eyes are situated far forward on the cheeks and are nearer the glabella than the posterior margin of the cephalon. The distance of the eye from the posterior margin of the cephalon is about 0.5 the length of the glabella. A faint eyeline is present. The neck-furrow is narrow and moderately deep. The whole cephalon is surrounded by a convex border which is rather wide on the cheeks, but very narrow in front of the glabella. The cephalon is covered with scattering pustules and the cheeks are in addition thickly indented with small pits. On the glabella, three pairs of pustules, two on the frontal lobe and one on the first segments are more strongly developed than the rest of the pustules. Of these, the second pair are the largest and resemble a pair of short, heavy, horn-like spines.

Comments.—The Kentland material referred to this species consists of a fragmental cranidium with the glabella and part of the right fixed cheek. It agrees closely with the description just given, especially in the forward expansion of the glabella (1 mm. to about every 3.6 mm.) and its termination at the frontal margin. Unfortunately, the frontal lobe and first glabellar lobe are partly chipped off, removing the prominent spines. The Kentland specimen is 11 mm. long, 11 mm. wide at the anterior margin, and 8 mm. wide at the neck-line; the one figured by Raymond and Barton is larger.

Occurrence.—Black River: Quebec. Kentland, Indiana: Div. 4-6, McCray quarry.

Ceraurus dentatus Raymond and Barton

Plate 10, Fig. 9

Ceraurus pleurexanthemus Hall (part), Pal. New York, **1**, 1847: 242, pl. 65, figs. 1d, h, i, m; pl. 66, figs. 1a-g.

Ceraurus dentatus Raymond and Barton, Bull. Mus. Comp. Zool., **54**, 1913: 534, pl. 1, fig. 2; pl. 2, figs. 4-5.—Shrock and Malott, Jour. Geol., 41, 1933: 347.

Description.—In distinguishing *C. dentatus* Raymond and Barton state:

> The larger specimens figured by Hall differ from the typical form of *Ceraurus pleurexanthemus* in having the eyes much further back and without eyelines, in the possession of much longer and less divergent genal spines, and in having two pairs of well developed spines on the pygidium, within the great spines.
>
> It might seem that these characters were merely the accompaniments of the greater size attained by specimens, but that such is not the case is shown by the fact that we have before us specimens of *C. dentatus* from Canada which are smaller than the large specimens from Trenton Falls. And, as has already been stated, series of specimens from Trenton Falls show that there is no backward movement of the eye or increase in the length of the genal spines with increase of size.

Comments.—The Kentland specimen referred to this species is smaller than those reported by Raymond and Barton, but has the same general proportions. The Coburg, Ontario specimen of Raymond and Barton is apparently somewhat smaller than the average. The following figures show how the two specimens compare:

	Ontario	Kentland
Length	74 mm.	
Width at genal angle	54 mm.	34 mm.
Length of cephalon	22.5 mm.	12 mm.
Length of glabella		9 mm.
Width of glabella (anterior)	17.5 mm.	8.5 mm.
Width of glabella (posterior)	13.5 mm.	7.0 mm.

The back of the eye in the Kentland specimen is much nearer the posterior margin of the cephalon than in *C. pleurexanthemus* (.22 of the length of the glabella as compared to from .40 to .58 of the length of the glabella), and the general outline of the cranidium is very similar to Raymond's figured specimens. Since the extremities of the genal spines are broken off, no statement can be made concerning their length.

Though Raymond states that *C. dentatus* is not known below the Trenton, the Kentland specimen, even though in rocks below the Trenton, may be assigned to that species.

A very small fragmental cranidium (glabella 4 mm. long), from Div. 8(15) of the Means quarry, may belong to this species.

Occurrence.—Trenton: New York; Ontario. Kentland, Indiana: Div. 8, (Div. 6-8, E. wall), McCray quarry; and Div. 8 (15), Means quarry.

Ceraurus pleurexanthemus Green

Plate 10, Fig. 8

Ceraurus pleurexanthemus Green, Monthly Amer. Jour. Geol., **1832**: 560, pl. 4, fig. 10.—Raymond and Barton, Bull. Mus. Comp. Zool., **54**, 1913: 528, pl. 1, fig. 1; pl. 2, figs. 1, 2, 7.—Shrock and Malott, Jour. Geol., **41**, 1933: 354.

Description.—The Kentland specimen referred to this species is a fairly complete cranidium, and has almost exactly the measurements given by Raymond (p. 532) for specimen No. 5. The eyes are situated far forward on the cheeks; a characteristic important in the identification of this species.

Occurrence.—Black River and Trenton: New Jersey, New York, Ohio, Minnesota, Tennessee; Canada. Kentland, Indiana: Div. 4-6, (and Div. 6-8 along E. wall), McCray quarry.

Calyptaulax cf. *eboraceus*

Plate 10, Fig. 3

Pterygometopus eboraceus Clarke, Geol. Minnesota, **3**, (2), 1897: 728, figs. 48, 49.—Shrock and Malott, Jour. Geol., **41**, 1933: 348.

Calyptaulax eboraceus Cooper, Amer. Jour. Sci., (5), **20**, 1929: 388.

Comments.—The single representative of the genus *Calyptaulax* included in the Kentland fauna comes from Div. 8(15) of the Means quarry and consists of a partly preserved cephalon with 8 thoracic segments partly exposed. A partial restoration of the specimen is shown on Plate 10, Fig. 3. It agrees with the descriptions and figures of *Pterygometopus eboraceus* by Clarke, but shows several features not mentioned in the description or shown in the illustrations. It is much smaller than the usual size; the width of the cephalon being only 12 mm. and the length the same. The cephalon is wider, in proportion to the width, than *P. eboraceus*, but this may be due to distortion during fossilization. The frontal lobe is wider in relation to the length. The second lateral furrows tend to trend obliquely backward and outward somewhat, whereas in *P. eboraceus* they lie almost at right angles to the body axis. Poor preservation of certain parts of the Kentland specimen makes its

specific identification uncertain, but of described species of *Calyptaulax*, it resembles *eboraceus* most closely[21]

Occurrence.—Trenton: New York. Kentland, Indiana: Div. 8(15), Means quarry.

OSTRACODA

Leperditia fabulites (Conrad)

Plate 10, Fig. 7; Plate 11, Fig. 1

Cytherina sp. Hall, Pal. New York, **1**, 1847: 44, pl. 10, fig. 12.

Cytherina fabulites Conrad, Proc. Acad. Nat. Sci., Philadelphia, **1**, 1843: 332.

Leperditia fabulites Jones, Ann. Mag. Nat. Hist., (2), **17**, 1856: 89; *ibid.*, (5), **8**, 1881: 342, pl. 20, fig. 4.—Greene, Contr. Ind. Pal., **2**, (1), 1906: 16, pl. A, fig. 1.—Shrock and Malott, Jour. Geol., **41**, 1933: 346 ff.

Comments.—This species of *Leperditia*, common in Black River—Trenton rocks, has been adequately described in many publications, and the Kentland specimens add nothing new. It is a common fossil in the Kentland rocks, and can be identified without difficulty, though the specimens show a variety of sizes.

Occurrence.—Black River: Minnesota, New York, Wisconsin; Canada. Stones River: Tennessee. Kentland, Indiana: Divs. 3, 4, 5, (6-8 along E. wall), 8, and 9, McCray quarry; Div. 8, McKee and Means quarries.

Leperditella persimilis Ulrich

Plate 10, Figs. 5A-C

Leperditella persimilis Ulrich, Geol. Minnesota, **3**, (2), 1897: 637, pl. 43, figs. 4-6.—Shrock and Malott, Jour. Geol., **41**, 1933: 346, 347.

Description.—Size.—(E. C.) Length 1.75 mm.; hight 1.23 mm.; thickness 0.8 mm. Carapace ovate, moderate convex, with the ends nearly equal; no dorsal angle behind but a well marked one in front; ventral overlap distinct; dorsal edge thick, shoulder like; greatest thickness central; surface smooth. The length varies between 1.5 mm. and 2.5 mm.

Comments.—Mr. Lloyd[22] described the Kentland specimens as follows:

Shell subelliptical in outline, moderately convex with the greatest convexity near the center. It measures about 2 mm. in length and 1½ mm. in height. The dorsal margin is straight with a rounded posterior extremity and an angular anterior extremity. The surface is smooth.

This species looks somewhat like *L. canalis* but is not as high, is less rounded and has the dorsal angle reversed.

We have not seen this species in any of the material recently obtained from Kentland, but it is known to be present. The figures are copies of drawings by Mr. Lloyd.

Occurrence.—Black River (Decorah): Minnesota. Kentland, Indiana: Div. 8(15), Means and McKee quarries.

---

21 Dr. David M. Delo examined the specimen and pointed out certain important features.

22 Lloyd, C. H. Unpublished A. M. thesis, University of Wisconsin, 1931: 33.

Leperditella sulcata (Ulrich)
Plate 11, Figs. 7-8

Leperditia sulcata Ulrich, Amer. Geol., **10**, 1892: 266, pl. 9, figs. 19-21.
Leperditella sulcata Ulrich, Geol. Minnesota, **2**, (2), 1897: 636, fig. 46j.

Comments.—The species is well represented in the upper part of Div. 8, McCray quarry, and in the same division of the Means quarry. The sulcus is usually fairly prominent, and the forms agree well with published descriptions and figures.

Occurrence.—Black River (Lowville): Kentucky, Tennessee, Virginia. Kentland, Indiana: Div. 8, Means and McCray quarries.

Leperditella tumida (Ulrich)
Plate 10, Fig. 1; Plate 11, Fig. 9

Leperditia tumida Ulrich, Amer. Geol., **10**, 1892: 264, pl. 9, figs. 1-3.
Leperditella tumida Ulrich, Geol. Minnesota, **3** (2), 1897: 636.—Shrock and Malott, Jour. Geol., **41**, 1933: 357.

Comments.—This species is especially abundant in the extreme northwest corner of the McCray quarry, just west of the ramp, in a gray, semi-lithographic limestone of "glass rock" lithology, and in similar beds in the Means quarry. The Kentland specimens closely duplicate the characteristics of the species as it occurs in Kentucky and Minnesota.

Occurrence.—Black River (Lowville): Kentucky, Tennessee, Virginia. Kentland, Indiana: Div. 8 (15, 19, 22), McCray quarry and Div. 8 (15), Means quarry.

Eurychilina subradiata Ulrich
Plate 11, Fig. 2

Eurychilina subradiata Ulrich, Jour. Cincinnati Soc. Nat. Hist., **13**, (1), 1890: 126, pl. 9, figs. 1a-c, 2a-c.

Comments.—A single right valve, showing the interior, is included in the Kentland fauna. It agrees so closely with published descriptions and figures that no further comment concerning it is necessary.

Occurrence.—Black River: (Platteville), Illinois; (Decorah), Minnesota. Stones River: Tennessee. Trenton (Canajoharie): New York. Kentland, Indiana: Div. 8(15), Means quarry.

Eurychilina ventrosa Ulrich
Plate 11, Fig. 3

Eurychilina ventrosa Ulrich, Geol. Minnesota, **3**, (2), 1897: 662, pl. 45, figs. 1-3.—Shrock and Malott, Jour. Geol. **41**, 1933: 347.

Comments.—Several left valves of this species are included in the Kentland fauna. All agree closely in size, contour and structure with published figures and descriptions.

Occurrence.—Trenton (Prosser): Minnesota. Kentland, Indiana: Div. 8(19, 22), McCray quarry and Div. 8(15), Means quarry.

Drepanella bigeneris Ulrich
Plate 11, Fig. 4

Drepanella bigeneris Ulrich, Geol. Minnesota, **3**, (2), 1897: 672, pl. 44, figs. 20-22.

Comments.—One large left valve is referred to this species. It is slightly

larger than the norm, and the ridges and nodes are larger than usual. Both of these abnormal features are due to the fact that the valve has been replaced by calcite and a certain amount of enlargement has resulted.

Occurrence.—Black River (Platteville): Minnesota. Kentland, Indiana: Div. 8(19), S. W. Corner of the McCray quarry.

Drepanella crassinoda Ulrich

Plate 11, Figs. 5-6

Drepanella crassinoda Ulrich, Jour. Cincinnati Soc. Nat. Hist., **13**, 1890: 118, pl. 8, figs. 1a-c.

Drepanella crassinoda Ulrich and Bassler, Proc. U. S. Nat. Mus., **35**, 1908: 291, fig. 18, pl. 41, figs. 4-6.

Comments.—Five fairly well preserved valves of this distinctive species are included in the Kentland fauna. All agree closely with figured specimens.

Occurrence.—Black River (Lowville): Kentucky, Tennessee, Virginia. Kentland, Indiana: Div. 8, McCray quarry and Div. 8(15), Means quarry.

Krausella arcuata Ulrich

Plate 10, Fig. 6

Krausella arcuata Ulrich, Geol. Minnesota, **3**, (2), 1897: 692, pl. 44, figs. 46-53.—Shrock and Malott, Jour. Geol., **41**, 1933: 347.

Comments.—A single right valve of this small ostracod is included in the Kentland fauna. It is fairly well preserved and shows the distinctive features of the species.

Occurrence.—Black River: Minnesota, Wisconsin (Platteville), Illinois; (Lowville), Kentucky. Kentland, Indiana: Div. 8(15), Means quarry.

APPENDIX

The following faunal lists, which have been reported from Kentland by various writers, are here appended in order to show what disposition of the numerous genera and species has been made in the foregoing discussion. Genera and species reported are shown in the left column; corrected identification and pertinent remarks appear in the right column.

Gorby (1883)[23]

Tetradium fibratum	*Tetradium cellulosum*
Zygospira modesta	*Zygospira recurvirostris*
Streptorhynchus sp.	Not found.
Leperditia sp.	*Leperditia fabulites*
Ptilodictya sp.	*Escharopora* sp.
Orthoceras sp.	Not found.
Glyptocrinus	Not found.

Gorby (1886)

Orthoceras simulator	These species, mainly Silurian
Orthoceras annulatum	in age, are believed to have been
Gyroceras or *Lituites* sp.	incorrectly identified and have not
Orthis testudinaria	been recognized.

Kindle and Breger (1904)

Orthoceras (Kionoceras) kentlandensis	Kionoceras kentlandense
Leperditia fabulites	*Leperditia fabulites*
Escharopora sp.	*Escharopora recta* or *subrecta*

23 For complete reference consult the Bibliography at the end of preceding paper.

Greene (1906)

Rhinidictya sp.	*Rhinidictya mutabilis*
Leperditella sp.	*Leperditella*, probably *persimilis*
Helopora sp.	*Helopora*, probably *alternata*
Poterioceras kentlandense	*Poterioceras kentlandense*

Foerste (1921)

Columnaria halli	Recognized
Rafinesquina minnesotensis	Recognized
Strophomena trentonensis	Recognized
Zygospira recurvirostris	Recognized
Ctenodonta nasuta	Recognized but not found
Actinoceras beloitense	Recognized but not found
Isotelus cf. *platycephalus*	Possibly *Isotelus gigas*.
Thaleops ovatus	Recognized

Foerste (1932, 1933)

Kentlandoceras schrocki	*Kentlandoceras shrocki*

Shrock and Malott (1933)

McKee Quarry:

Dalmanella testudinaria	Not recognized
Leperditella persimilis	Identification checked
Leperditia fabulites	Identification checked
Poterioceras kentlandensis	*Poterioceras kentlandense*
Rhinidictya mutabilis	Identification checked
Rhinidictya paupera	Identification incorrect. Probably *R. mutabilis*
Tetradium cellulosum	Identification checked
Zygospira recurvirostris	Identification checked

Means Quarry:

Beatricia n. sp.	*Kentlandia imbricata* gen. et sp. nov.
Bumastus milleri	Identification checked
Ceraurus dentatus	Identification checked
Cryptophragmus antiquatus	Identification checked
Escharopora angularis	Identification checked
Escharopora recta	Identification checked
Escharopora subrecta	Identification checked
Eurychilina ventrosa	Identification checked
Helopora mucronata	Identification checked
Krausella arcuata	Identification checked
Leperditella canalis	Not recognized. Misidentification
Leperditella persimilis	Identification checked
Leperditia fabulites	Identification checked
Orthis tricenaria	*Hesperorthis tricenaria*
Primitiella simulans	Not recognized. Misidentification
Pterygometopus eboraceus	*Calyptaulax* cf. *eboraceus*
Rafinesquina alternata	*Rafinesquina* sp.
Rafinesquina minnesotensis	Identification checked
Rhinidictya mutabilis	Identification checked
Rhynchotrema minnesotense	Identification checked
Zygospira recurvirostris	Identification checked

McCray Quarry (Sandstone):

Endoceras sp.	The present writers accept the
Liospira sp.	identifications by Mr. G. O.
Modiolopsis sp.	Raasch. There is not yet available
Orthodesma sp.	enough material sufficiently well
Sphenolium n. sp.	preserved to warrant any specific
Tript[er]oceras sp.	identifications. More and better preserved specimens will probably alter this list.

McCray Quarry (chiefly the "molluscan fauna"):

Actinoceras sp. (cf. *libanum*)	Not recognized.
Ambonychia n. sp.	*?Ambonychia* cf. *attenuata*
Beatricia n. sp.	*Kentlandia imbricata* sp. nov.
Bucania halli	*Salpingostoma buelli*
Ceraurus pleurexanthemus	Identification checked
Clathrospira subconica	Identification checked
Clionychia n. sp.	*Clionychia triangularis* sp. nov.
Columnaria sp.	*Columnaria halli*
Clisiospira occidentalis	Not recognized
Cryptophragmus antiquatus	Identification checked
Ctenodonta cf. *levata*	Provisional identification checked
Ctenodonta logani	*Ctenodonta* cf. *logani*
Cyrtodonta huronensis	*Cyrtodonta* cf. *huronensis*
Doleroides perveta	Not recognized
Valcouria deflecta	*Valcourea deflecta*
Eccyliomphalus undulatus	Identification checked
Eotomaria cf. *labiosa*	*Eotomaria trochoides* sp. nov.
Holopea similis	*Holopea ampla*
Hormotoma gracilis	*Hormotoma gracilis angustata*
Hormotoma gracilis angustata	Identification checked
Hyolithes baconi	Identification checked
Isotelus gigas	Identification checked
Kentlandoceras shrocki	Identification accepted
Leperditia fabulites	Identification checked
Leperditella tumida	Identification checked
Liospira cf. *abrupta*	Not recognized
Liospira n. sp. (near *angustata*)	Not recognized
Liospira conradana	Identification checked
Liospira oweni	*Liospira oweni kentlandensis* var. nov.
Liospira perangulata	Identification checked
Liospira serrulata	Identification checked
Pholidops trentonensis minor (?)	Identification checked
Phragmolites grandis	Identification checked
Doleroides perveta	Not recognized
Pterotheca attenuata	*Pterotheca* cf. *attenuata* and *Pterotheca intermedia* sp. nov.
Pterotheca expansa	Identification checked
Rafinesquina minnesotensis	Identification checked
Rhynchotrema minnesotense	Identification checked
Salterella billingsi	Identification checked
Scolithus sp.	Questionable
Stenotheca sp.	*Stenotheca kentlandensis* sp. nov.
Strophomena sp.	*Strophomena* sp.
Strophomena incurvata	*Strophomena plattinensis*
Subulites sp.	Generic identification checked
Tetradium sp.	*Tetradium cellulosum*
Tetradium carterensis	*Kentlandia irregularis* sp. nov.
Tetranota wisconsinensis	Identification checked
Thaleops ovatus	Identification checked
Triptoceras n. sp. (large and small)	*Tripteroceras indianense* sp. nov.
Valcouria deflecta	*Valcourea deflecta*
Vanuxemia rotundata	Identification checked
Vanuxemia n. sp. (cf. *niota* Hall)	*Vanuxemia sulcata* sp. nov.
Whitella n. sp.	Not recognized
Zygospira recurvirostris	Identifications checked
Zygospira saffordi	Identification checked

UNIVERSITY OF WISCONSIN,
MADISON, WISCONSIN

AND

MAGNOLIA PETROLEUM COMPANY,
OKLAHOMA CITY, OKLAHOMA.

PLATE 1

FIGURES

1–3. *Columnaria halli* Nicholson.

1. Cross-section of a fragmental corallum from the southwest corner of the McCray quarry (Div. 9), showing size and shape of corallites, and septa. x 2.75.

2. Longitudinal section from same specimen as Fig. 1, showing tabulae and septa (in lower left corner). x 2.75.

3. Fragmental corallum from floor of McCray quarry at north end (Div. 10), showing the prominent septal ridges. x 0.9.

4. *Tetradium cellulosum* (Hall)
Cross-section of several corallites of a specimen from Div. 8(17), McKee quarry, showing the shape of the corallites and the disposition of the prominent septa. x 9.

5–13. *Kentlandia imbricata* Shrock gen. et sp. nov.

5. Cross-section of a corallum from Div. 7, McCray quarry, showing the imbrication of the corallites and the radial structure on the inner side of the outer convex wall of the corallite. x 2.75.

6. Highly magnified portion of Fig. 5, showing radial structure mentioned above. x 5.5.

7. Longitudinal section of same specimen as Figs. 5 and 6, showing the calcite-filled corallites and the radial structure inside the corallite walls. x 2.75.

8. Cross-section of a small portion of the peripheral zone of a corallum from Div. 7, McCray quarry, showing the scalloped external surface caused by the imbrication of the corallites. x 2.75.

9. Highly magnified cross-section of part of a corallum from Div. 7, McCray quarry, showing the imbrication of the corallite walls. Little radial structure is preserved because of its replacement by coarsely crystalline calcite. x 9.

10. Cross-section of part of a corallum from Div. 7, McCray quarry, showing asymmetry of corallum, scalloped periphery, imbrication of corallite walls, and central prismatic tube (indicated by arrow). x 2.75. (Holotype, No. 501, Geological Museum, University of Wisconsin).

11. Cross-section of a polished specimen from Div. 7, McCray quarry, showing three coralla. x 0.6.

12, 13. Longitudinal and cross-sections, respectively, of a fragmental corallum from Div. 7, McCray quarry. x 2.75.

PLATE I

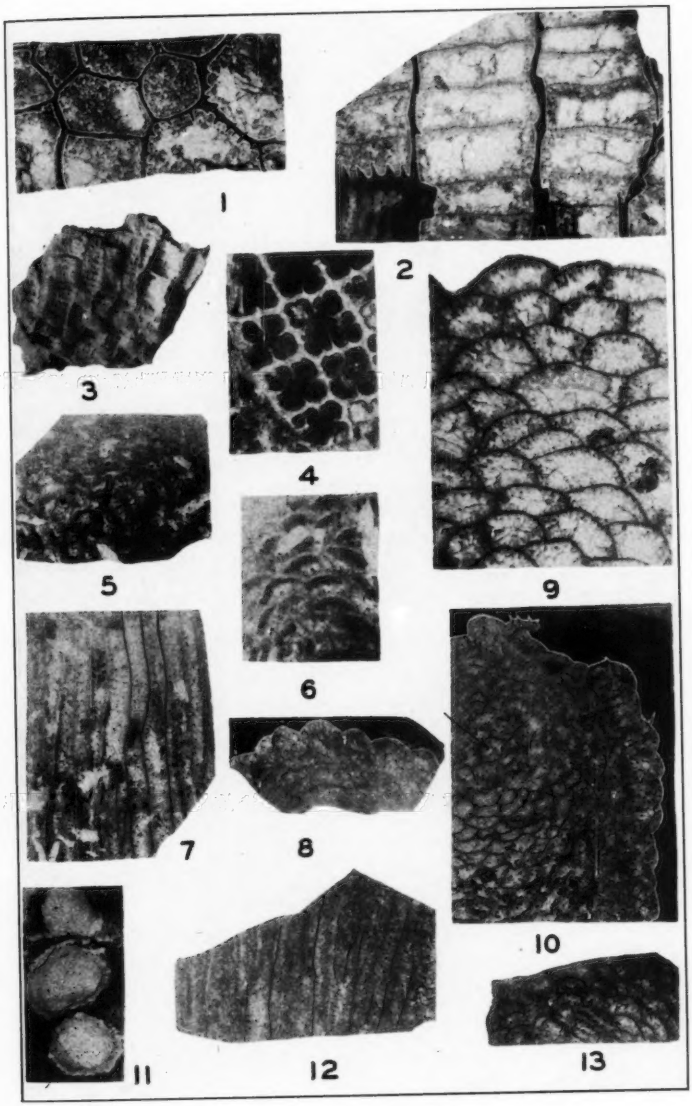


PLATE 2

FIGURES

1–3. *Cryptophragmus antiquatus* Raymond.

1. Polished surface showing the longitudinal sections of two specimens from Div. 7, Means quarry. x 0.9.

2. Longitudinal section of a specimen from Div. 7, Means quarry, showing the inner, calcite-filled tube with its convex partitions and wall of vesicular tissue surrounded by a thin, calcite-filled zone (between the white lines). x 2.75.

3. Cross-section of a large specimen from Div. 7, Means quarry, showing the inner, calcite-filled tube with its surrounding zone of vesicular tissue. A convex partition is shown in cross-section by a thin band in the central part of the tube. x1.

4. *Kentlandia imbricata* Shrock gen et sp. nov.
Diagrammatic sketch of part of a corallum, based on sectioned specimens from Div. 7, McCray quarry. x 2.

5–8. *Kentlandia irregularis* Shrock sp. nov.

5. Longitudinal section of part of a polished specimen from Div. 7, McCray quarry, showing several corallitees. x 0.9.

6. Cross-section of a stem (polished) of a corallum (reconstructed in Fig. 8) from Div. 7, McCray quarry, showing size, shape and arrangement of corallites. Note the irregular shape, variable size and irregular arrangement of the corallites. x 0.9. (Holotype, No. 502, Geological Museum, University of Wisconsin.)

7. Cross-section of a polished surface of part of a corallum from Div. 7, McCray quarry, showing the same features as Fig. 6. x 1.8.

8. Diagrammatic sketch of the holotype from Div. 7, McCray quarry, based on serial sections. Note especially the irregular shape and arrangment of the corallites, as compared with Fig. 4, and also the branching. The individual stems of the corallum do not enlarge in diameter very rapidly. The basal part of the sketch shows the two stems before bifurcation. x 0.45. (Holotype, No. 502, Geological Museum, University of Wisconsin).

PLATE 2

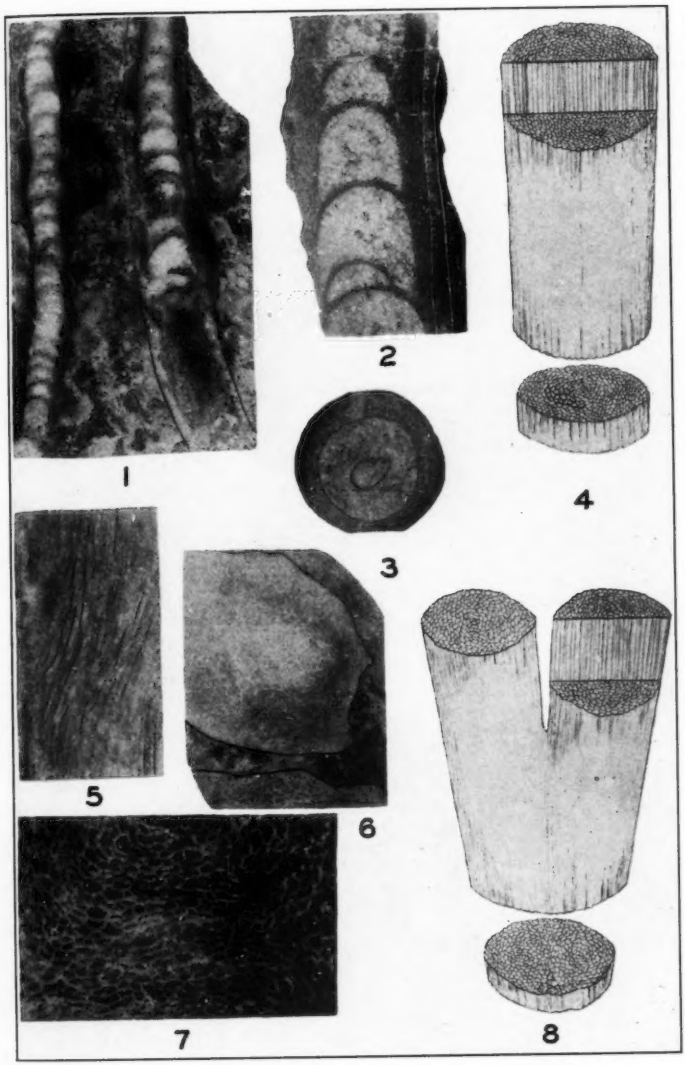


PLATE 3

FIGURES

1. *Helopora mucronata* Ulrich.
   Retouched photograph of the basal part of a segment from Div. 8(15), Means quarry. x 9.
2. *Helopora alternata* Ulrich.
   Camera lucida drawing of a segment from Div. 8(15), Means quarry. x16.

3, 11–12, 15. *Helopora spiniformis* (Ulrich).

3. A segment from Div. 8(15), Means quarry. x 5.5.

11, 12. Two fragments of stems from Div. 8(15), Means quarry. x 5.5.

15. An almost complete segment from Div. 8(15), Means quarry. x 2.25.

4. *Helopora pulchella* Shrock sp. nov.
   Slightly retouched photograph of the holotype, an almost complete segment from Div. 8(15), Means quarry, showing the marked quincuncial arrangement of the zooecial apertures. x 3.6. (Holotype, No. 503, Geological Museum, University of Wisconsin).
5. *Escharopora subrecta* (Ulrich).
   Basal part of a specimen from Div. 8(15), Means quarry. x 5.5.

6–7. *Escharopora recta* Hall.

6. Highly magnified portion of a small specimen from Div. 8(15), Means quarry, showing symmetrical arrangement of zooecial apertures. x 10.
7. Outline of a large, complete specimen from Div. 8(15), Means quarry. x 0.9.
8. *Nicholsonella pulchra* Ulrich.
   Camera lucida drawing of a tangential section (thin section) of a specimen from Div. 5, McCray quarry, showing the arrangement of the zooecia and position and arrangement of the spines. x 36.
9. *Rhinidictya exigua* Ulrich. Div. 8(15), Means quarry. x 4.5.
10. *Rhinidictya mutabilis* (Ulrich).
    A fragmental zoarium from Div. 8(17-18), McKee quarry, showing the typical noncelluliferous border. x 4.5.

13, 16. *Escharopora angularis* Ulrich.

13. A nearly complete specimen from Div. 8(15), Means quarry. x 5.5.
16. A nearly perfect specimen from Div. 8(15), Means quarry, with a specimen of *Rhinidictya* sp. x 1.25.

14, 18, 19. *Crania setigera* Hall.

14. A flattened specimen from Div. 8(15), Means quarry, showing the prominent pustules along the outer border. x 2.25.
18. A typical specimen from Div. 8(15), Means quarry, showing the prominent pustules along the outer border of the shell. x 0.9.
19. Magnified view of Fig. 18. x 2.25.
17. *Rhinidictya* sp.
    A poorly preserved specimen from Div. 8(15), Means quarry. x 1.
20. *Pholidops trentonensis minor* Winchell and Schuchert.
    View of the impression of the surface of a dorsal (?) valve from Div. 4-6, McCray quarry, showing the prominent growth lines and distinct beak. x 3.5.

21–24. *Hesperorthis tricenaria* (Conrad).

21. Internal filling of ventral valve of a shell from the Platteville of Wisconsin, introduced in place of poorly preserved specimens from Kentland. x 0.9.
22. View of the exterior of the flat dorsal valve of a specimen from Div. 8(15), Means quarry. x 0.9.
23. View of the interior of a dorsal valve from Div. 8(15), Means quarry. The part of the shell to the right of the white line is restored. x 2.25.
24. View of the interior of a small dorsal valve (partly restored) from Div. 8(15), Means quarry, considerably magnified. x 5.5.

PLATE 3

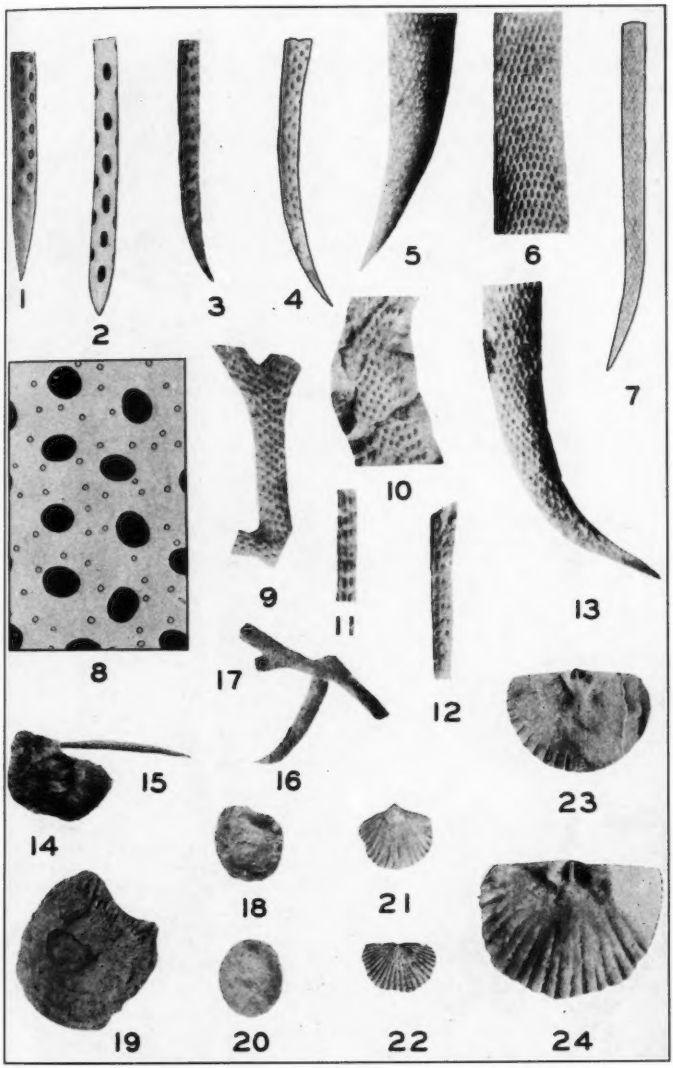


PLATE 4

FIGURES

1–2, 4. *Strophomena plattinensis* Fenton.

1, 2. Internal fillings of two ventral valves from the same slab of Platteville (Lower Buff) dolomite, 1 mile south of Aztalan, Jefferson County, Wisconsin, showing the relatively wide and shallow muscle area, the acute lateral angles, and the shallow concavity which characterizes the ventral valve of this species. x 0.9.

4. Internal filling of a young ventral valve, perfectly flat at this stage of growth, from Divs. 4-6, McCray quarry. x 1.

3, 7. *Strophomena plattinensis crassa* Raasch var. nov.

3. Internal filling and external mold of a nearly flat dorsal valve from the Platteville (Blue Beds), 2 miles west of Klevenville, Dane County, Wisconsin. x 0.9.

7. Interior of ventral valve from the Platteville (Blue Beds) at Beloit, Wisconsin. x 1. (Differs from the typical form in having both valves decidedly flatter and in having the posterolateral angles nearly rectangular). (Holotype, No. 504, Geological Museum, University of Wisconsin).

5. *Rhynchotrema minnesotense* (Sardeson).
Internal filling of ventral valve from Divs. 4-6, McCray quarry. x 0.9.

6, 8. *Strophomena auburnensis impressa* Raasch var. nov.

6. Ventral interior from the Platteville (Upper Buff), Beloit, Wisconsin, with valve so oriented as to foreshorten the visceral area. x 0.9. (Holotype, No. 505, Geological Museum, University of Wisconsin).

8. Internal filling of dorsal valve from the Platteville, 3 miles south of New Glarus, Green County, Wisconsin. x 0.9. (Differs from the typical form in having the vascular markings deeply impressed in the median portion of the ventral valve. Dorsals probably not distinguishable).

9. *Strophomena auburnensis* Fenton.
Ventral interior from the Spechts Ferry, lower division, at Liberty Pole, Vernon County, Wisconsin. x 0.9. (Differs from *S. plattinensis* in the elongate ventral muscle area, with its pointed anterior extremities, and in more strongly developed brachial apparatus and prominent median septum of the dorsal valve).

10. *Strophomena winchelli* Hall and Clarke.
Ventral interior from the Platteville (Blue Beds), 1½ miles west of Pine Bluff, Dane County, Wisconsin. x1. This species is readily distinguished by its small size, lobate anterior extension of shell, and short, transverse muscle area.

11, 14. *Strophomena musculosa* Fenton.

11. Dorsal interior partly filled with matrix from the Gutenberg at the highway junction, 3 miles south of Viroqua, Vernon County, Wisconsin. x 1.

14. Ventral interior from the Gutenberg at Redmound, near Victory, Vernon County, Wisconsin. x 1. The illustration fails to bring out the high convexity. The species is readily distinguished by its high convexity and by the strongly upturned edges of the equidimensional muscle area.

12. *Valcourea deflecta* (Conrad).
Internal filling of a dorsal valve from Divs. 4-6, McCray quarry. x 0.5.

13. *Rafinesquina minnesotensis inquassa* (Sardeson).
Dorsal interior from Div. 8, northeast corner of McCray quarry. x 0.9.

15. *Rafinesquina minnesotensis* (N. H. Winchell).
Internal filling of a ventral valve from Divs. 4-6. McCray quarry. x 0.75.

PLATE 4

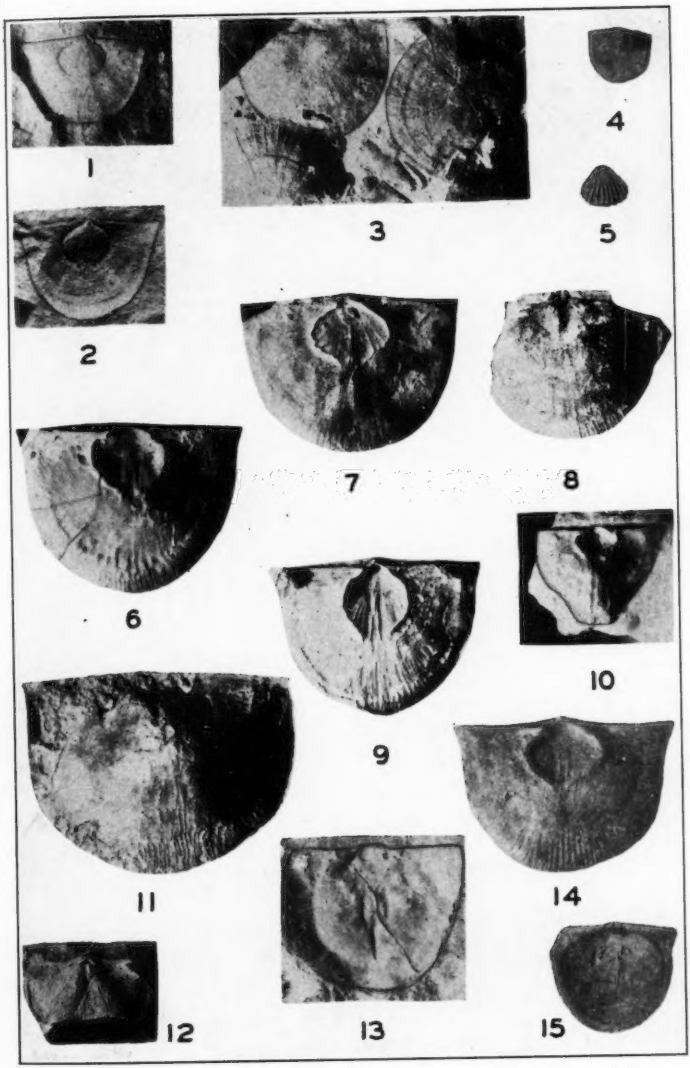


PLATE 5

FIGURES

1–4. *Strophomena plattinensis* Fenton.

1. Internal filling of a dorsal interior, showing virtual absence of median septum. x 0.9.

2. Internal filling of a dorsal valve of less than average size. x 0.9.

3. Squeeze of an internal filling of a ventral valve. The strong transverse lighting gives an appearance of greater relief to the borders of the muscle area than is warranted. x 0.9.

4. Internal filling of ventral valve, showing the low convexity and the shape and depth of the muscle area. x 0.9.

(All specimens from Divs. 4-6, McCray quarry).

5. *Glyptorthis bellarugosa* (Conrad).

Fragmentary ventral valve preserving the diagnostic surface ornamentation, which is rather indistinctly shown in the illustration. Div. 8, northeast corner of McCray quarry. x 0.9.

6. *Leptaena charlottae* Winchell and Schuchert.
Dorsal interior from Div. 8, northeast corner of McCray quarry. x 1.

7. *Pterotheca* cf. *attenuata* (Hall).

An internal filling, from Divs. 4-6, McCray quarry, which as it stands agrees with Hall's species. Since, however, the only important difference between the latter and our proposed *intermedia* lies in the width of the lateral border, and since the outer edge of the border is not preserved in the specimen, positive identification is impossible. A number of other specimens, all from Divs. 4-6, are in a similar condition. x 0.9.

8–9, 13. *Pterotheca expansa* (Emmons).

8. Mold of the under side of the septum and a portion of the internal filling of a shell from Divs. 4-6, McCray quarry. x 1.

9. Similar aspect with the lateral borders well preserved. x 1.

13. Partial internal and external molds of a shell. x 0.9.
(9 and 13 from the Platteville (Lower Buff) of Wisconsin.

10–12. *Pterotheca intermedia* Shrock sp. nov.

10, 11. Counterparts of the holotype showing the attenuate septum and very broad lateral borders which characterize this species. From Divs. 4-6, McCray quarry. x 0.9. (Holotype, No. 513, Geological Museum, University of Wisconsin).

12. Partial external and internal molds of a shell from Div. 4-6, east wall of McCray quarry. 0.9.

PLATE 5

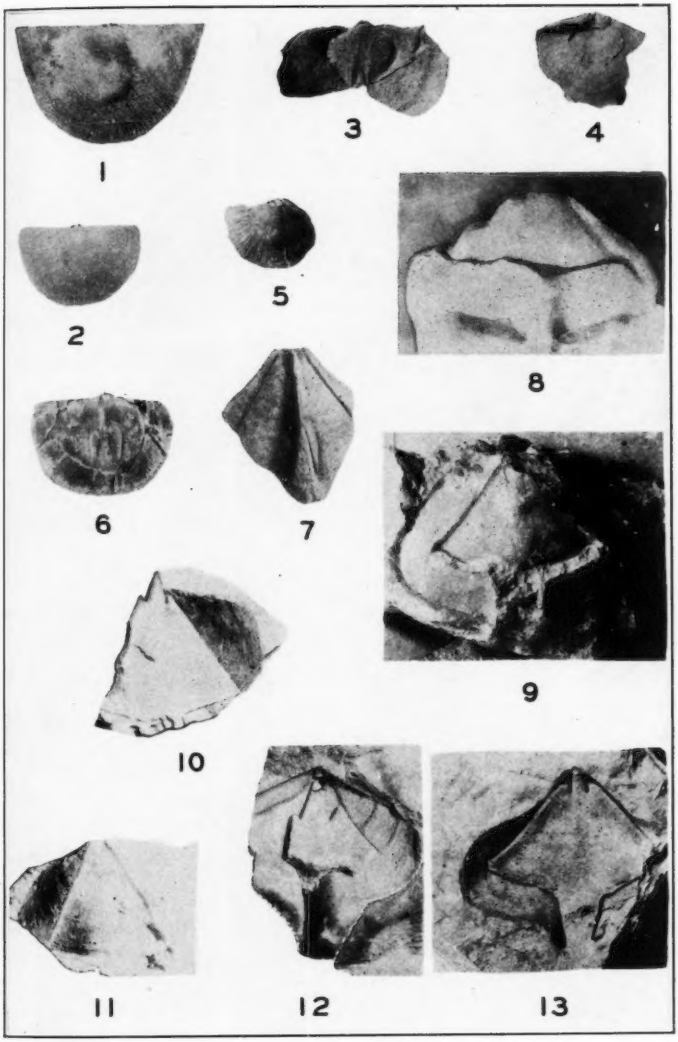


PLATE 6

FIGURES

1–2. *Ambonychia* cf. *attenuata* Hall.
Retouched photographs of a left valve from Divs. 4-6, McCray quarry, showing anterior (1) and lateral (2) views. x 0.9.

3. *Clionychia triangularis* Raasch sp. nov.
The holotype, an internal filling of the right valve, from Divs. 4-6, McCray quarry. x 1. (Holotype, No. 508, Geological Museum, University of Wisconsin).

4–6, 9. *Vanuxemia decipiens kentlandensis* Raasch var. nov.

4. Internal filling of left valve from Divs. 4-6, McCray quarry. x 1. (Holotype, No. 506, Geological Museum, University of Wisconsin).

6, 9. Dorsal and lateral views, respectively, of an internal filling of a right valve from Divs. 4-6, McCray quarry. x 0.9.

5. Dorsal view of a complete internal filling of a shell from Divs. 4-6, McCray quarry. x 1.

7. *Vanuxemia sulcata* Raasch sp. nov.
The holotype, an internal filling of the left valve, from Divs. 4-6, McCray quarry. x 0.9. (Holotype, No. 507, Geological Museum, University of Wisconsin).

8. *Ctenodonta socialis* Ulrich.
An internal filling of right valve from Divs. 4-6, McCray quarry. x 1.75.

10–11. *Vanuxemia rotundata* (Hall).

10. Internal filling of right valve from Divs. 4-6, McCray quarry. x 1.

11. Anterior view of a complete internal filling from Divs. 4-6, McCray quarry. x 1.

12. *Cyrtodonta* cf. *huronensis* Billings.
Internal filling of right valve from beds bearing *Tetradium cellulosum*, Div. 8(17), northwest corner of McCray quarry. x 1.

13. *Ctenodonta gibberula* Salter.
Internal fillings of two valves from Div. 8 or 9, McCray quarry. x 0.9.

14. *Lyrodesma* cf. *acuminatum* Ulrich.
Internal filling showing umbonal portion of a fragmentary valve containing the diagnostic subrostral hinge plate. Div. 9, McCray quarry. x 1.

15–16. *Ctenodonta* cf. *logani* Salter.
Internal fillings of two right valves from Divs. 4-6, McCray quarry. x 0.9.

17–18. *Ctenodonta ovata robusta* (Ulrich).
Two lateral views of an internal filling from Div. 6, McCray quarry. Fig. 17 is tilted in order to show the hinge teeth. x 0.9.

PLATE 6

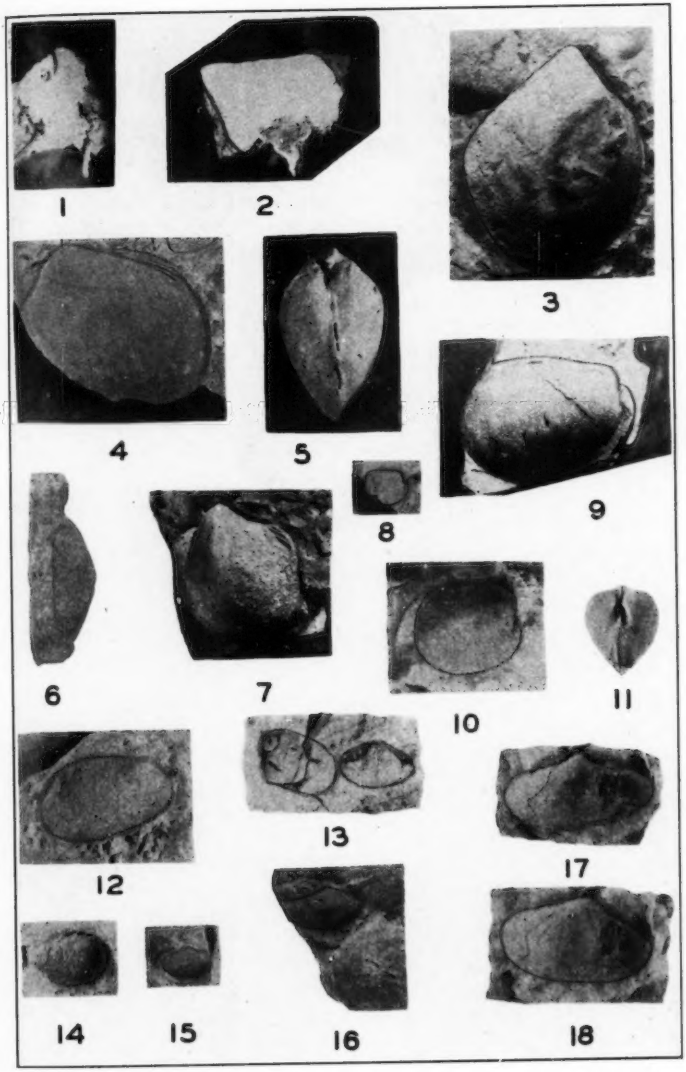


PLATE 7

FIGURES

1. *Ophiletina sublaxa* Ulrich and Scofield.
Squeeze of a mold of the underside of a shell from Div. 6 or 8, east wall of McCray quarry. x 0.9.

2–3. *Eccyliopterus* sp. nov., aff. *beloitensis* Ulrich and Scofield.
Squeeze showing the upper side of shell, and mold from which it was made. Specimen from Divs. 4-6, McCray quarry. x 0.9.

4. *Eccyliomphalus undulatus* (Hall).
Lower side of an internal filling from Divs. 4-6, McCray quarry. x 0.9.

5–6. *Holopea ampla* Ulrich and Scofield.
Two views of a poorly preserved internal filling of the last whorl: (5), dorsal view; x 0.9.; (6), top view; x 1.75. Specimen from Divs. 4-6, McCray quarry.

7–9, 12–13. *Stenotheca kentlandensis* Raasch sp. nov.
7. Lateral view of the smallest individual. x 1.75.

8–9, 13. Right and left lateral, and top views of the holotype. x 0.9.
12. Basal outline of the holotype showing asymmetrical nature. x 0.9.
Specimens from Divs. 4-6, McCray quarry. (Holotype, No. 512, Geological Museum, University of Wisconsin.)

10, 23–24. *Cyrtodonta* cf. *billingsi* Ulrich.
(Differing from the examples of the typical form figured herewith in being narrower anteriorly, in showing a distinct umbonal ridge and furrow, and in possessing a marked thickening of the shell internally between the pallial line and the ventral margin). All specimens from Divs. 4-6, McCray quarry.

10. Internal filling of a right valve, showing the cardinal teeth. x 0.9.
23. Left aspect of paired valves. x 0.9.
24. The largest and best preserved example—an internal filling of the left valve. x 1.

11, 18, 20–21. *Cyrtodonta billingsi* Ulrich.
(All specimens from Divs. 4-6, McCray quarry)

11. Internal filling of a young right valve. x 1.
18. Well preserved internal filling of a left valve. x 1.
20. Internal filling of a broken left valve showing hinge teeth. x 1.
21. Internal filling of a left valve showing hinge teeth. x 1.75.

14–15. *Hyolithes baconi* Whitfield.
14. Dorsal view of internal filling from Divs. 4-6, McCray quarry. x 0.9.
15. Impression of operculum from Divs. 4-6, McCray quarry. x 0.9.

16–17. *Salterella billingsi* Safford.
Squeeze of several external molds (16) and specimen showing external molds and internal fillings (17) from Divs. 4-6, McCray quarry. x 0.9. (Outlines are retouched).

19. *Spyroceras cylindratum* Foerste.
Squeeze taken from an external mold in the brown dolomitic limestone in the east wall of the McCray quarry (Divs. 6-8). x 0.9.

22. *Ctenodonta* cf. *levata* (Hall).
Camera lucida drawing, with outline restored from a photograph, of a specimen from Divs. 4-6, McCray quarry. x 2.75.

PLATE 7

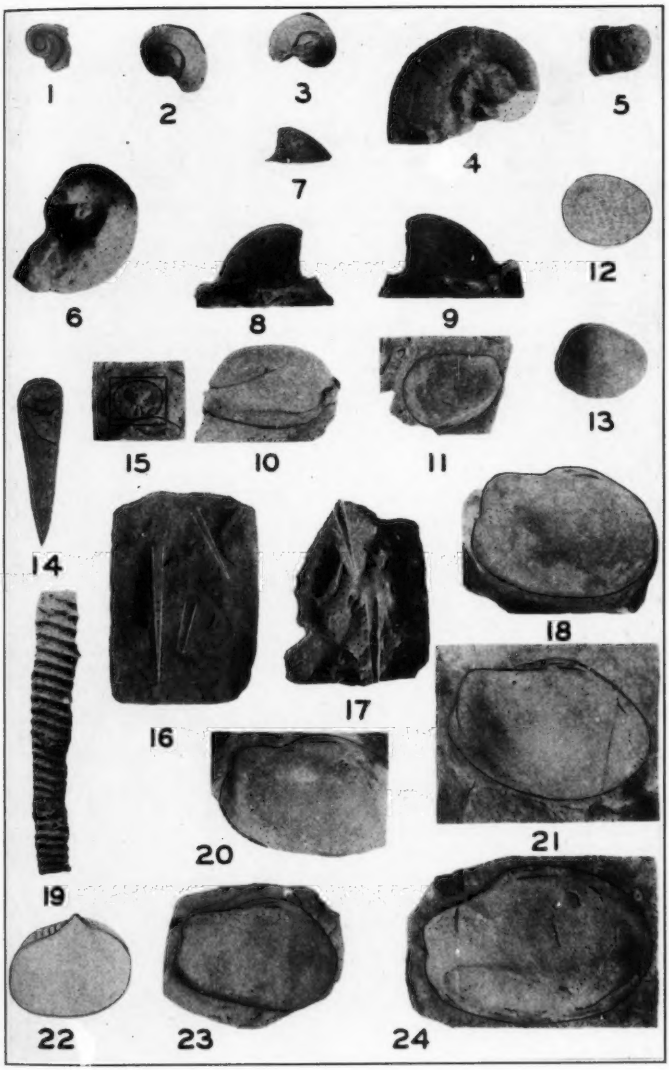


PLATE 8

FIGURES

1–3. *Tetranota wisconsinensis* (Whitfield).

1. Dorsal view of an internal filling. x 1.

2. Squeeze of the inner side of a whorl showing the characteristic revolving carinae. x 1.

3. Umbilical view of an internal filling. x 1.
(All specimens from Divs. 4-6, McCray quarry).

4. *Salpingostoma buelli* (Whitfield).
Dorsal view of a fragment of an internal filling preserving a portion of the closed terminal part of the slit-band. Specimen from Divs. 4-6, McCray quarry. x 0.9.

5. *Raphistomina* cf. *modesta* (Ulrich).
Top view of a fragmental internal filling from Divs. 4-6, McCray quarry. x 1.

6–8. *Phragmolites grandis* (Ulrich).

6, 7. Lateral views of two shells. Both are external molds on which is impressed the distinctive surface sculpture. Part of the internal filling is apparent in Fig. 6. Specimens from Divs. 4-6, McCray quarry. x 0.9.

8. Specimen showing a cross-section of the whorl near the apex and the larger portion of the internal filling. Divs. 4-6, McCray quarry. x 1.

9. *Lophospira conradana* Ulrich and Scofield.
Internal filling of a small individual from Divs. 4-6, McCray quarry. x 1.

10–11. *Lophospira oweni kentlandensis* Raasch var. nov.

10. Squeeze of an internal mold, Divs. 4-6, McCray quarry. x 0.9.

11. The holotype, an internal filling, from Divs. 4-6, McCray quarry. x 0.9. (Holotype, No. 509, Geological Museum, University of Wisconsin).

12. *Lophospira serrulata* (Salter).
Squeeze of a part of an internal mold in which the spinose peripheral carina is particularly well shown. Div. 8, east wall of McCray quarry. x 0.9.

13. *Lophospira sexlineata* Raasch sp. nov.
Squeeze of an external mold, the holotype, from Divs. 4-6, McCray quarry, showing a dorsal view. x 0.9. (Holotype, No. 510, Geological Museum, University of Wisconsin).

14–16. *Liospira obtusa* Ulrich and Scofield.

14. Top view of an internal filling. x 0.9.

15. View of the underside of an internal filling, showing the limestone matrix filling the open umbilicus. x 0.75.

16. Top view of a squeeze taken from the counterpart of Fig. 14, showing the surface characters. x 0.75.
(All specimens from Divs. 4-6, McCray quarry)

17. *Liospira* sp.
A weathered internal filling from Div. 7, McCray quarry.

18–19. *Eotomaria trochoides* Raasch sp. nov.
Squeeze of the external mold (18), and the internal filling of the holotype from Divs. 4-6, McCray quarry. (Fig. 19 is incorrectly oriented). x 0. 9. (Holotype, No. 511, Geological Museum, University of Wisconsin).

20–21. *Clathrospira subconica* (Hall).
Squeeze of an internal mold (20) and an internal filling (21), from Divs. 4-6, McCray quarry. x 1.

PLATE 8

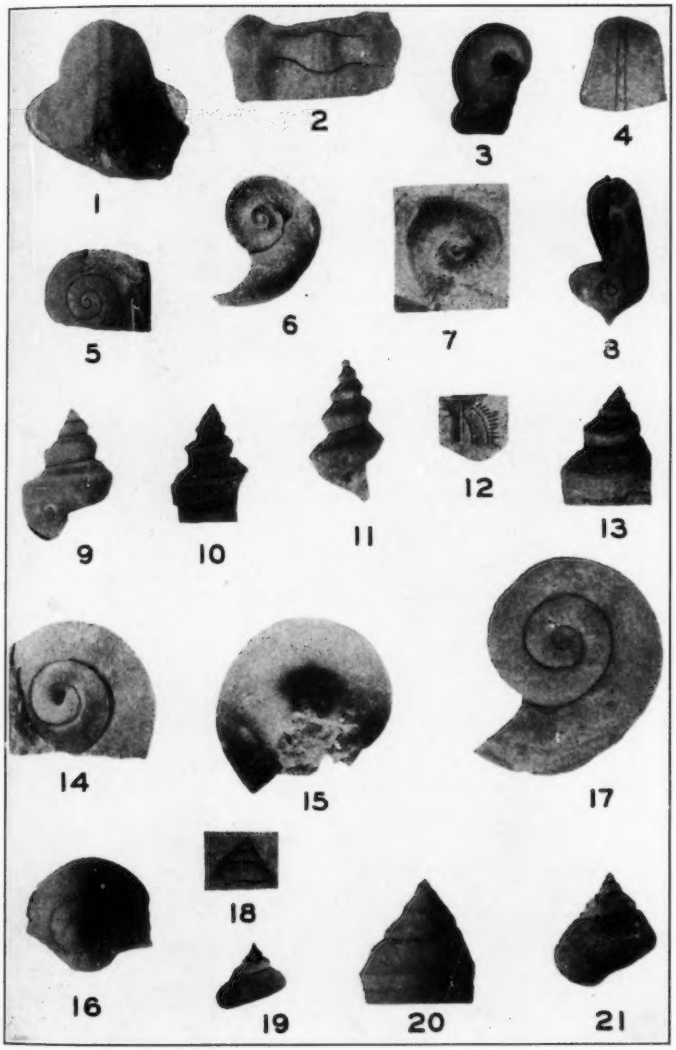


PLATE 9

FIGURES

1. *Kionoceras kentlandense* (Kindle and Breger).

   A copy of the original figure. x 1.2. Horizon unknown.

2–3. *Kentlandoceras shrocki* Foerste.

2. Foerste's original figure of the holotype showing a lateral view with convex ventral margin on the left. x 0.9.

3. Foerste's original figure of the holotype showing a ventral view with glimpses of the siphuncle. x 0.9.

   Specimen from Divs. 4-6, McCray quarry. (Holotype, No. 87116, U. S. National Museum).

4. *Tripteroceras indianense* Raasch sp. nov.

   View of holotype, from Divs. 4-6, McCray quarry, showing a filling of the living chamber, and external mold of a camera. x 0.9. (Holotype, No. 514, Geological Museum, University of Wisconsin).

5–6. *Whitfieldoceras mumiaforme* (Whitfield).

5. View of a specimen from the Platteville at Beloit, Wisconsin, introduced for comparison. x 0.9.

6. View of a small specimen from Divs. 4-6, McCray quarry, showing several camerae and the general porportions of the shell. x 0.9.

7. "*Orthoceras*" cf. *sociale* Hall.

   View of a specimen from Divs. 4-6, McCray quarry, showing the proportions of the shell, size and position of the siphuncle and character of the camerae. The basal portion of the living chamber is also visible. x 0.9.

8–9. *Poterioceras kentlandense* Rowley.

8. Copy of Rowley's original figure of the holotype, showing the cross-section and the size and position of the siphuncle. x 0.7.

9. Copy of Rowley's original figure of the holotype, showing a ventral view, with a portion of the shell removed to show the siphuncle. x 0.6.

   Specimen from Div. 8, McKee quarry. (Holotype—whereabouts unknown).

PLATE 9

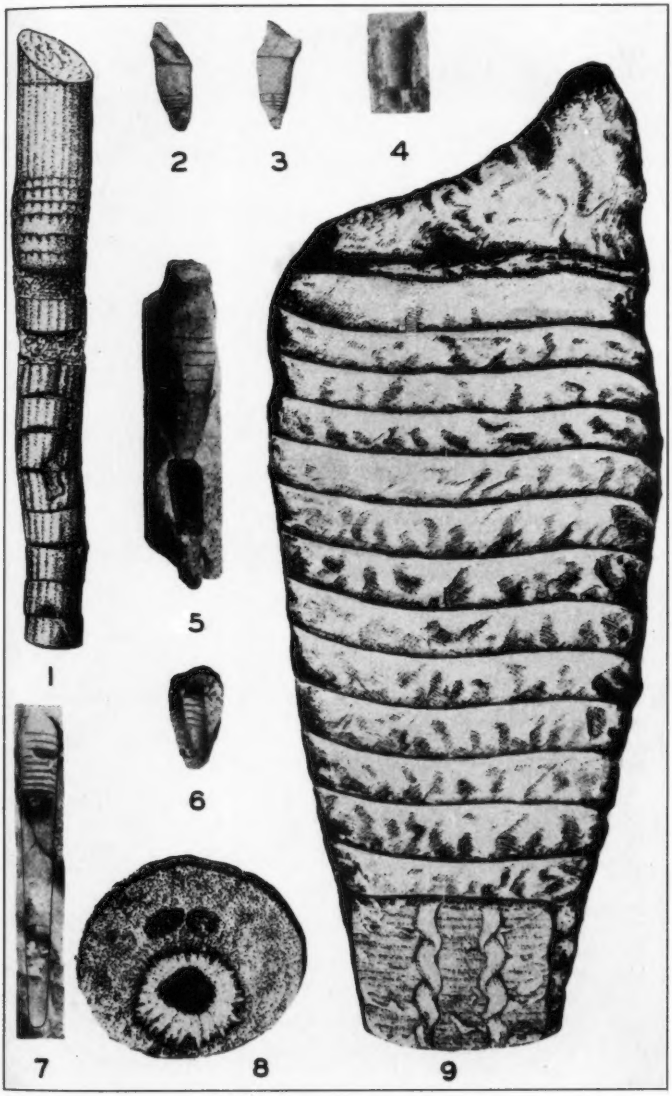


PLATE 10

FIGURES

1. *Leperditella tumida* (Ulrich).
Camera lucida drawing of a large right valve from Div. 8, McCray quarry. x 18.

2 A–E. *Thaleops ovatus* Conrad.
(All figures are camera lucida drawings of specimens from Divs. 4-6, McCray quarry).

2A. A small cranidium. x 0.9.

2B. Right side of a cranidium showing the well developed genal spine. x 0.9.

2C. A pygidium. The lateral and anterior margins are shown straighter than they really are. x 0.9.

2D. Longitudinal section of 2C.

2E. Transverse section of 2C. (The top and sides are shown too straight.)

3. *Calyptaulax* cf. *eboraceus* (Clarke).
Camera lucida drawing of a fragmental cephalon, in part restored, from Div. Div. 8(15), Means quarry. x 2.75.

4 A–C. *Bumastus milleri* (Billings).
(Specimen from Div. 7, Means quarry)

4A. Camera lucida drawing of a cranidium, showing the outline, and the position of the small distinctive depressions. x 1.8.

4B. Transverse section of 4A.

4C. Longitudinal section of 4A.

5 A–C. *Leperditella persimilis* Ulrich.

5A. Camera lucida drawing of a right valve from Div. 8, Means quarry. x 9.

5B. Longitudinal section of 5A.

5C. Transverse section of 5A, with dorsal edge on the left.

6. *Krausella arcuata* Ulrich.
A right valve from Div. 8(15), Means quarry, showing distinctive posterior spine. x 14.

7. *Leperditia fabulites* (Conrad).
A weathered left valve from Div. 8, north wall of McCray quarry. x 0.9.

8. *Ceraurus pleurexanthemus* Green.
View of a fragmental cranidium from Divs. 4-6, McCray quarry, showing the forward position of the facial suture. x 0.9.

9. *Ceraurus dentatus* Raymond and Barton.
View of an almost complete cranidium from Divs. 4-6, McCray quarry, showing the position of the facial suture. x 0.9.

10. *Ceraurus bispinosus* Raymond and Barton.
View of an incomplete cranidium from Divs. 4-6, McCray quarry, showing the character of the glabella. x 0.9.

11–13. *Isotelus gigas* DeKay.

11, 12. Pygidia from Divs. 4-6, McCray quarry. x 0.9.

13. Fragmental cranidium from Div. 8, McCray quarry. x 0.9.

14. *Bathyurus spiniger* (Hall).
View of an incomplete cranidium, from Div. 8, north wall of McCray quarry, showing the characteristic spinose surface. x 0.9.

PLATE 10

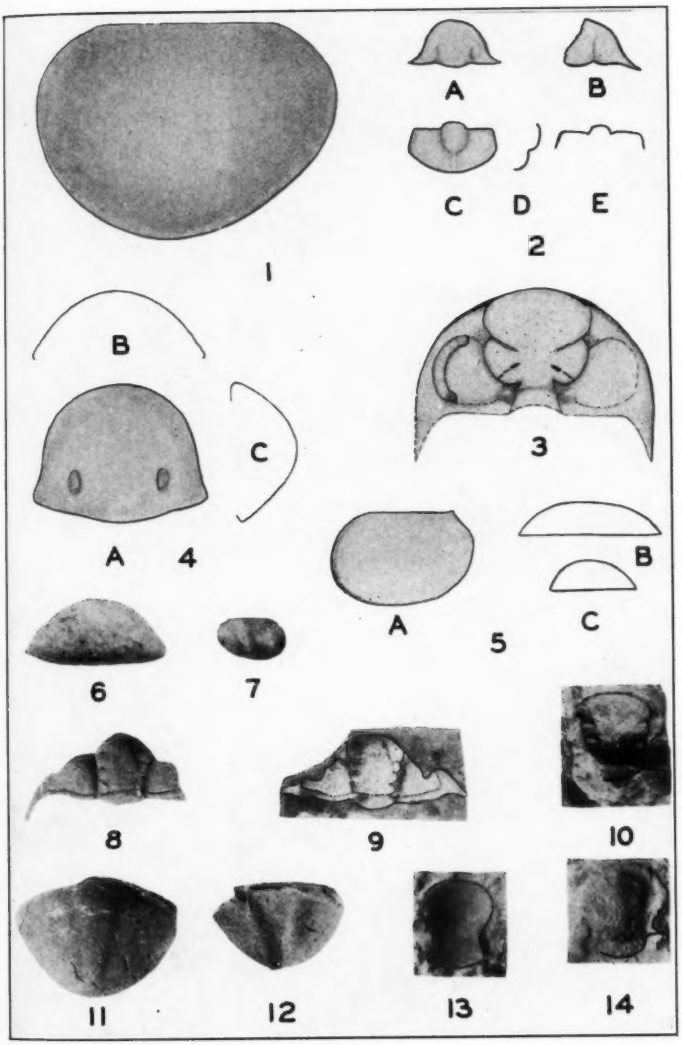


PLATE 11

(All figures on this plate are camera lucida drawings of actual specimens)

FIGURES

1. *Leperditia fabulites* Conrad.

   View of the right valve of a shell from Div. 8, McCray quarry, surrounded by the outline of a larger right valve of the same species from the same locality and horizon. x 5.5.

2. *Eurychilina subradiata* Ulrich.

   View of the interior of a right valve of a shell from Div. 8(15), Means quarry. x 18.

3. *Eurychilina ventrosa* Ulrich.

   View of the left valve of a shell from Div. 8(19 or 22), north wall of McCray quarry. x 18.

4. *Drepanella bigeneris* Ulrich.

   Side view of the left valve of a large shell from Div. 8, southwest corner of McCray quarry. The shell and its features appear larger than normal because of replacement and consequent enlargement. x 18.

5–6. *Drepanella crassinoda* Ulrich.

5. Side view of a right valve from Div. 8, southwest corner of McCray quarry. x 14.

6. Side view of a left valve from Div. 8, Means quarry. x 14.

7–8. *Leperditella sulcata* (Ulrich).

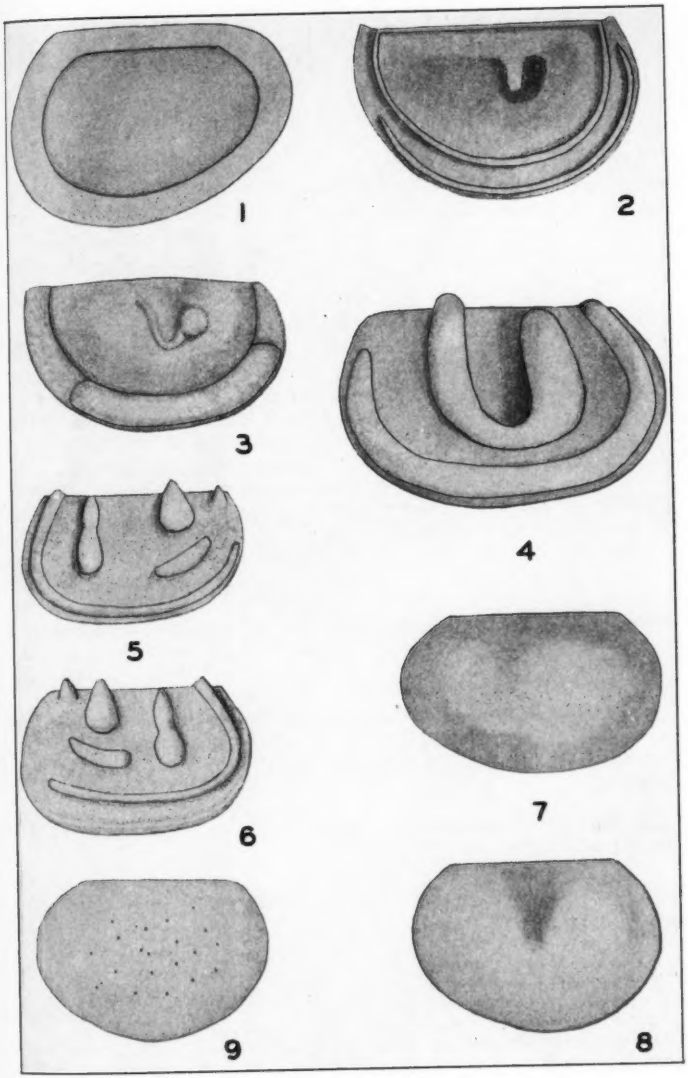
7. View of a left valve from Div. 8, McCray quarry, showing a somewhat elongated form with a prominent sulcus. x 18.

8. View of a left valve from Div. 8, McCray quarry, showing a somewhat higher and shorter form. x 18.

9. *Leperditella tumida* (Ulrich).

   View of a left valve from Div. 8, McCray quarry, showing the characteristic minute punctae. x 18.

PLATE 11



Skull of Musk-Ox, Genus Symbos, from Montgomery County, Indiana

Marcus Ward Lyon, Jr., and Fred T. Hall

On July 12, 1936, Victor Mahan, who resides near Crawfordsville, was hunting turtles on the Ingersol farm in Ripley Township, Montgomery County. While searching along a small, superficial stream, locally called Mill Creek, he noticed a horn protruding from the mud and gravel and uncovered an unusual skull. The specimen, brought to Crawfordsville and placed in a local barber shop window, excited considerable curiosity.

It was identified by Dr. Leo Murray and by the senior author as an almost perfect example of the extinct Musk-Ox, *Symbos cavifrons* (Leidy). The specimen is about as perfect as the one from Hebron, Porter County, in the American Museum of Natural History, and probably not quite so perfect as the one in the paleontological collection of the University of Michigan. This, so far as we are aware, is the eighth specimen of this genus to be unearthed in Indiana, a larger number than has been recorded from any other state.

The topography of the country where it was found is practically level, and Mill Creek is little more than a mere trickle. Its bed is about five feet below the surrounding country. It is probable that the skull had been washed from some other place into the one in which it was found, because excavation around the spot where it was discovered yielded no other bones. The skull, however, is in such perfect condition that it could not have been subjected to much rough washing. The soil all around, while obviously drift, is of fine material.

In the autumn the specimen was acquired by the United States National Museum, which has very kindly given us the photographs of it which are shown on Plates 1 & 2. Its catalogue number is 14428, Division of Vertebrate Paleontology.

The important measurements made by the junior author while the skull was in Crawfordsville are:

MEASUREMENTS IN MILLIMETERS

Total length of skull (unreconstructed)	570
Height of skull, at rear, from lower surface of occipital condyles to top of posterior portion of exostosis	233
Width across articular surface of occipital condyles	131
Width between openings of external auditory canals	188
Greatest width of posterior nares	55
Approximate length of horn cores along posterior convexity	420

Anteroposterior diameter of horn core 70 mm. from median plane of skull	100
Anteroposterior length of exostosis	240
Tip of horn core to center of exostosis	400
Greatest diameter of orbit	75
Length of maxillary tooth row (alveoli)	180
Three molars present on each side of the jaw	
Orbit to anterior end, incomplete	300
Distance between tips of horn cores	565
Greatest width across jugals below anterior margin of orbits	246

The genus *Symbos* is by far the commoner of the two Musk-Oxen known in the middle west, there being comparatively few finds of *Ovibus*, the Musk-Ox which is found today in northeastern North America and Greenland, and which in Pleistocene times had a much wider existence.

As to the nature of the covering of the exostosis, occupying nearly the whole top of the skull, no one can tell. In general it has the roughened appearance of the base of the horns of the Rhinoceros, and it also resembles the base of the horn cores of the present day Musk-Ox. It is probable that this exostosis was covered with horny material, although it is improbable that a third horn protruded from it because the exostosis itself is scooped out; and for that reason *Scaphoceros* was the name originally applied to the genus by Osgood (Smiths. Misc. Coll., vol. 48, p. 177, pls. 40-42, 1905.) Later the name was changed to *Symbos* (Proc. Biol. Soc. Wash. vol. 18, p. 224, 1905, Oct. 17) because *Scaphoceros* was preoccupied. The animal would thus appear to have had a sort of frontal shield uniting the two horns. It is unlikely that the exostosis was covered with normal skin and hair.

The skulls of *Symbos* which have been found appear to be so recent in their general aspect that one would almost expect to see the true horny material covering the horn cores. But it is probable that such material was rapidly eaten by insects or perhaps other animals. The skull in question shows the tooth marks of undetermined rodents. That the animal disappeared in the late Pleistocene is suggested by the superficial depths at which most of the remains are found.

Thanks are due Messrs. C. W. Gilmore and C. Lewis Gazin for verifying the original measurements and supplying some additional ones.

PLATE 1

Plate 1—Dorsal and left lateral views of the skull of *Symbos cavifrons* (Leidy). U. S. National Museum, No. 14428. Courtesy of the U. S. National Museum.

PLATE 2

Plate 2.—Ventral and posterior views of the skull of *Symbos cavifrons* (Leidy), U. S. National Museum, No. 14428. Courtesy of the U. S. National Museum.

Ectoparasites of the Blunt-Nosed Minnow

(Hyborhynchus notatus)

John D. Mizelle

Previous to 1934 the taxonomy of American fresh-water Gyrodactyloidea received little attention. Investigations were directed more toward control measures with a minimum amount of effort devoted to specific diagnosis. In the above mentioned year Justus F. Mueller gave comprehensive consideration to the group and later wrote several papers with additional descriptions and records of new forms. The present writer (1936) published an abstract of a doctor's thesis in which he briefly described twelve new species of *Tetraonchinae* from the gills of Illinois fishes. To date fifty-four species of monogenetic trematodes of the subfamilies *Gyrodactylinae*, *Dactylogyrinae* and *Tetraonchinae* have been reported from the gills of North American fresh-water fishes. Eight of these belong to the genus *Gyrodactylus*, two to the genus *Dactylogyrus*, and forty-four to the subfamily *Tetraonchinae*. Including the three forms described in this paper the species of *Dactylogyrus* known to North America now total five. Of the above trematodes all are indigenous to North America except *Tetraonchus monenteron* (Wegener, 1857); *Gyrodactylus elegans* Nordman, 1832; and *Dactylogyrus anchoratus* (Dujardin, 1845). These three species were first described from Europe.

In preference to the inclusion of the genus *Dactylogyrus* in the subfamily *Gyrodactylinae* as given by Johnston and Tiegs in 1922, the family *Dactylogyridae* Bychowsky, 1933, is accepted by the present writer. Price (1937) lists forty-eight valid species of *Dactylogyrus* of which only one, *D. extensus* Mueller and Van Cleave, 1932, was originally described from this continent. Another form, *D. anchoratus* originally described from Europe has been reported from North America.

Parasites in this study were killed according to the method described by Mizelle (1936) for members of the *Tetraonchinae*. Terminology for structures is reviewed in the same paper. All measurements except those of the cirrus, anchors, bars and hooks were made on specimens mounted in a mixture of equal parts of glycerine and water without the addition of a cover glass to the preparation. Measurements of the cirrus, anchors, bars and hooks were made with a cover glass on the preparation. Curved structures were measured as a straight line extending between the two extremities of such structures. For instance in the case of a sickle-shaped cirrus, as in *D. simplex* sp. nov., the measurement consists of a straight line connecting the base and tip of the cirrus. Measurements of anchor lengths extend from the tip of the superficial root to the most distant point of the curved portion of the anchor in the region of junction of the shaft and point. Each mean measurement is a calculated average derived from measurements (one each)

of the same structure in twenty different individuals. Eighteen mean measurements of different structures were derived for each species described making a total of three hundred-sixty measurements per species.

Specimens for permanent mounts were selected microscopically with a bulb-equipped capillary pipette and placed individually on clean slides in a drop of glycerine. Excess fluid was removed with a pipette leaving the specimen somewhat adherent to the slide. Rapid immersion of the preparation into seventy per cent alcohol further fixed the specimens to the slides so that mounting was easily accomplished.

It has been found that unstained specimens permit better observation of chitinous structures than do stained mounts. For instance in the case of *Onchocleidus mucronatus* Mizelle, 1936, the cirral thread wound around the cirrus shaft is the only portion of the copulatory complex that takes the stain (Ehrlich's acid haematoxylin and borax carmine). Stained surrounding tissues often obscure the small accessory piece and tubular cirrus, both of which remain transparent, so that the observer unfamiliar with the species gets the impression that a cirral thread and accessory piece are absent and that the cirrus (cirral thread in reality) exists as a corkscrew-like structure which is not uncommon in other members of the same genus *(O. principalis* Mizelle, 1936).

Dactylogyrus bychowskyi sp. nov.

Host: Blunt-nosed Minnow *(Hyborhynchus notatus)*, Embarras River and Drainage Ditch, Urbana, Illinois.

(Figs. 1-5)

Relatively small gill trematodes of a somewhat fusiform nature. Average length about 0.381 mm. (0.285-0.615 mm.), average width at level of cephalic lobes about 0.057 mm. (0.040-0.086 mm.), greatest body width average about 0.079 mm. (0.049-0.108 mm.), average width of peduncle at junction with the haptor about 0.044 mm. (0.030-0.067 mm.). Haptor distinct, knob-like, at times assuming a sub-pentagonal shape and broader than long, average width about 0.072 mm. (0.050-0.095 mm.), average length about 0.059 mm. (0.048-0.068 mm.). The single pair of anchors is located dorsally with their superficial bases connected by a solid chitinous bar. Bases of anchors bifurcate, superficial root noticeably longer than the deep root. Anchor shafts (solid in fresh preparations, small cavity in permanent mounts) make junction with the points to form a distinct internal angle. Average length of anchors about 0.048 mm. (0.038-0.057 mm.), average width of anchor bases 0.020 mm. (0.015-0.028 mm.). A ventral bar of "ventrales Chitinstück" or "Chitinklammer" of German workers, has not been observed in this species. Average length of dorsal bar about 0.021 mm. (0.017-0.025 mm.). Each of the fourteen hooks present is differentiated into a base, shaft, sickle-shaped termination and opposable piece. Hook bases ovate and very short as compared with the length of the shafts. Hooks of pairs numbers one and five slightly shorter than the rest of the hooks. The arrangement of the hooks is similar to that of forms in the tetraonchid genera *Cleidodiscus* Mueller,

1934, and *Onchocleidus* Mueller, 1936. Forms that have been removed to the genus *Actinocleidus* Mueller, 1937, have been excluded.

Hook pair	Average length in mm.	Range in mm.
1	0.015	0.013-0.017
2	0.017	0.015-0.019
3	0.017	0.015-0.19
4	0.018	0.015-0.21
5	0.014	0.011-0.17
6	0.017	0.013-0.021
7	0.017	0.015-0.019

Eye spots four in number, approximately equal in size and with members of each pair about the same distance apart. Gonads located near the middle of the body, testis ovate, situated dorso-posterior to and smaller than the ovary. Vas deferens passes forward near the median line of the body as a slightly undulant tube. Seminal vesicle lies near the copulatory complex base and consists of an elongate dilatation of the vas deferens. Two prostates present near the copulatory complex base, one bulbular in shape, the other botuliform, each emptying into the cirrus base by a single individual duct. Copulatory complex well developed and situated in a relatively large vestibule. Cirrus an elongate hollow chitinous tube tapering to a point distally and with a digitiform projection arising from the base (Fig. 3). Average length of cirrus 0.044 mm. (0.038-0.051.). Accessory piece a solid chitinous blade-like structure with a knob present about half-way its length. The proximal portion of the accessory piece is articulated with the base of the cirrus. Ovary ovate in shape, larger than the testis and with spatial relationships as given above. The oviduct arises from the anterior end of the ovary and passes forward near the midline of the body. Uterine pore located on the ventral body surface in the region of the copulatory complex. Vagina present on the right body margin in the posterior portion of the anterior body half. Vaginal tube chitinous and connected with a small clear ovate seminal receptacle. Vitellaria present as two lateral bands of individual vitelline follicles, generally confluent anteriorly and always confluent posteriorly near the peduncle. Vitelline ducts empty into the oötype immediately anterior to the ovary. Mouth located ventrally in the region of the anterior eye spots, buccal canal short, emptying into a relatively massive pharynx, average diameter about 0.038 (0.029-0.048 mm.). Intestinal crura traversing the lateral body regions and uniting posteriorly in the region of confluency of the vitellarial bands. Excretory ducts confluent posteriorly near the peduncle, ending blindly anteriorly and lateral to the anterior eye spots. One excretory pore located on each body margin approximately at the level of the distal portion of the copulatory complex.

Dactylogyrus bychowskyi possesses a copulatory apparatus similar to that of *D. amphibothrium* Wagener, 1857, but is different from the latter species in the possession of a digitiform process on the cirrus base. The anchors, hooks and bars of the two species differ in shape and size relationships. *D. amphibothrium* is found on *Acerina cernua* whereas *D. bychowskyi* occurs on *Hyborhynchus notatus*.

Dactylogyrus bifurcatus sp. nov.

Host: Blunt-nosed Minnow *(Hyborhynchus notatus)*, Embarrass River and Drainage Ditch, Urbana, Illinois.

(Figs. 6-11)

Relatively small gill trematodes of a somewhat fusiform nature. Average length about 0.343 mm. (0.254-0.492 mm.), average width at level of the cephalic lobes about 0.051 mm. (0.038-0.065 mm.), greatest body width average about 0.070 mm. (0.049-0.095 mm.), average width of peduncle at junction with haptor about 0.038 mm. (0.019-0.042 mm.). Haptor distinct, sub-discoidal in shape and broader than long, average width about 0.062 mm. (0.049-0.087 mm.), average length about 0.044 mm. (0.023-0.057 mm.). The single pair of anchors is located dorsally with their superficial bases connected by a solid chitinous bar. Bases of anchors bifurcate, superficial root longer than deep root. Anchor shafts (solid in fresh preparations, small cavity in permanent mounts) regularly recurved without formation of an angle at junction of shafts and anchors. Wings present on the anchor shafts. Average length of anchors about 0.033 mm. (0.028-0.034 mm.), average width of anchor bases about 0.012 mm. (0.008-0.013 mm.). Ends of ventral bar slightly bent posteriorly with a short median projection on the anterior border and about the same length as the dorsal bar. Average length of dorsal bar about 0.017 mm. (0.015-0.023 mm.). Each of the fourteen hooks present is differentiated into a base, shaft, sickle-shaped termination and opposable piece. Hook bases elongate and nearly as long as the shafts. Hooks of pair number one slightly shorter than the rest of the hooks. The arrangement of the hooks is similar to that of forms in the tetraonchid genera *Cleidodiscus* Mueller, 1934, and *Onchocleidus* Mueller, 1936.

Hook pair	Average length in mm.	Range in mm.
1	0.016	0.013-0.019
2	0.018	0.015-0.021
3	0.019	0.015-0.023
4	0.018	0.015-0.021
5	0.017	0.015-0.019
6	0.018	0.013-0.019
7	0.017	0.015-0.019

Eye spots four in number, about the same size and with members of the two pairs about the same distance apart. Gonads situated near the middle of the body, testis globular located posterior to and much larger than the ovary. Vas deferens passes forward near the median line of the body as a slightly undulant tube. Seminal vesicle lies near the copulatory complex and consists of an elongate dilatation of the vas deferens. The single prostate which lies near the copulatory complex base is bulbular in shape. Copulatory complex well developed and situated in a small vestibule. Cirrus a short curved chitinous tube tapering to a point distally. Average length of cirrus about 0.029 mm. (0.027-0.030 mm.). Accessory piece a solid chitinous structure bifurcate distally and with the proximal portion articulated to the cirrus base. Ovary ovate in shape, smaller than the testis and with spatial relationships as given above. The oviduct arises from the anterior end of the ovary and passes forward near the midline of the body. Uterine pore located on the

ventral body surface in the region of the copulatory complex. The vagina and seminal receptacle have not been observed in this species. Vitellaria present as two lateral bands of individual vitelline follicles generally confluent anteriorly and always confluent posteriorly on the peduncle. Vitelline ducts empty into the oötype immediately anterior to the ovary. Mouth located ventrally between the anterior eye spots, buccal canal short, emptying into the well developed pharynx, average diameter about 0.022 mm (0.019-0.027 mm.). Intestinal crura traverse the lateral body regions and unite posteriorly in the region of confluency of the vitellarial bands. Excretory ducts confluent posteriorly near the peduncle, ending blindly anteriorly and lateral to the eye spots. One excretory pore located on each body margin approximately at the level of the distal portion of the copulatory complex.

The morphology of *Dactylogyrus bifurcatus* conforms in the general generic morphology, but differs from other members of the genus by the possession of a short distally bifurcate accessory piece.

Dactylogyrus simplex sp. nov.

Host: Blunt-nosed Minnow *(Hyborhynchus notatus)*, Embarrass River and Drainage Ditch, Urbana, Illinois.

(Figs. 12-17)

Relatively small gill trematodes of a general fusiform shape. Average length about 0.324 mm. (0.189-0.443 mm.), average width at level of the cephalic lobes about 0.045 mm. (0.038-0.057 mm.), greatest body width average about 0.062 mm. (0.044-0.076 mm.), average width of peduncle at junction with haptor about 0.036 mm. (0.023-0.048 mm.). Haptor distinct, irregularly discoidal in shape, and broader than long, average width about 0.056 mm. (0.042-0.074 mm.), average length about 0.038 mm. (0.029-0.048 mm.). The single pair of anchors is located dorsally with their superficial bases connected by a solid chitinous bar. Bases of anchors bifurcate, superficial root longer than deep root. Anchor shafts solid and regularly recurved without formation of an angle at junction of shafts and points. Wings present on the anchor shafts. Average length of anchors about 0.028 (0.027-0.034 mm.), average width of anchor bases 0.012 mm. (0.008-0.017 mm.). Ends of ventral bar bent posteriorly with a short median projection on the anterior border and about the same length as the dorsal bar. Average length of dorsal bar about 0.019 mm. (0.017-0.021 mm.). Each of the fourteen hooks present is differentiated into a base shaft, sickle-shaped termination and opposable piece. Hook bases elongate and nearly as long as the shafts. Hooks of pair number one slightly shorter than the rest of the hooks. The arrangement of the hooks is similar to that of forms in the tetraonchid genera *Cleidodiscus* Mueller, 1934, and *Onchocleidus* Mueller, 1936.

Hook pair	Average length in mm.	Range in mm.
1	0.015	0.011-0.017
2	0.017	0.015-0.019
3	0.018	0.015-0.023
4	0.017	0.015-0.023
5	0.016	0.011-0.021
6	0.016	0.013-0.017
7	0.017	0.014-0.023

Eye spots four in number, approximately equal in size and with members of each pair about the same distance apart. Gonads situated in the first portion of the posterior body half. Testis globular, located posterior to and much larger than the ovary. Vas deferens passes forward near the median line of the body as a slightly undulant tube. Seminal vesicle lies near the copulatory complex and consists of a dilatation of the vas deferens. Two prostates present near the copulatory complex base, one bulbular in shape, the other elongate, each emptying into the cirrus base by a single individual duct. Copulatory complex well developed and situated in a large vestibule. Cirrus a hollow sickle-shaped chitinous tube tapering to a point distally. Average length of cirrus about 0.024 mm. (0.019-0.029 mm.). Accessory piece a solid chitinous structure with a knob present near the mid-length. The proximal portion of the accessory piece is articulated with the base of the cirrus. Ovary ovate in shape, smaller than the testis and with spatial relationships as given above. The oviduct arises from the anterior end of the ovary and passes forward near the midline of the body. Uterine pore located on the ventral body surface in the region of the copulatory complex. The vagina and seminal receptacle are not clearly discernible in this form. Vitellaria present as two lateral bands of individual vitelline follicles generally confluent anteriorly near the posterior margin of the pharynx, whose average diameter is about 0.022 mm. (0.019-0.025 mm.). Intestinal crura traverse the lateral body regions and unite posteriorly in the region of the confluency of the vitelline bands. Excretory ducts confluent posteriorly near the peduncle, ending blindly anteriorly and lateral to the eye spots. One excretory pore located on each body margin approximately at the level of the distal portion of the copulatory complex.

Dactylogyrus simplex is closely related morphologically to *D. anchoratus* (Dujardin, 1845); *D. intermedius* Wegener, 1909; and *D. macracanthus* Wegener, 1909. *D. simplex* differs from these three related species in the shape and size relationships of the copulatory complex, anchors, bars and hooks. *D. anchoratus* occurs on *Carassius carassius, Carassius auratus,* and *Cyprinus carpio; D. intermedius* on *Carassius carassius; D. macracanthus* on *Tinca tinca;* and *D. simplex* on *Hyborhynchus notatus.*

Discussion

In a recent publication Mueller (1937) mentioned two systems of numbering the hooks on haptors of fresh-water species of North American *Tetraonchinae.* Contentions regarding the order of these structures are not of a serious nature, and only for the sake of future workers in this field are the following comparisons and deductions set forth. It must be remembered that any arbitrary system of numbering that deals with haptoral hooks in this group of parasites, cannot be regarded as indicative of unquestionable value. Such information must be attained through embryological studies. In the absence of such evidence, all systems of numbering must be regarded as highly artificial, derived solely as a matter of convenience and discarded when more basic evi-

dence is produced. Information concerning the embryology of North American *Tetraonchinae* is as yet wanting.

In 1936 Mueller sought to number the hooks consecutively around the margin of the haptor beginning with the anterior central pairs of hooks as number one. This system suffices very well for forms in which all seven pairs of hooks lie on the same side of the haptor, ex. *Actinocleidus articularis* (Mizelle, 1936) and the present writer in 1936 retained it for such forms. In the majority of species of this subfamily, however, five pairs of hooks are situated on the ventral and two pairs of hooks on the dorsal side of the haptor instead of all being on one surface. The dorsal pairs of hooks are variable in their positional relationships (in different species) with the five pairs of ventral hooks, so that the earlier proposed system of numbering (Mueller 1936) becomes very confusing for these forms. Discrepancies naturally occur in the older system of numbering because of this fluctuation in the linear positions of the two pairs of hooks mentioned. For instance the most anterior dorsal hook is labelled number six by Mueller for *Onchocleidus mimus* (1936, p. 59, pl. 13, fig. 13), two for *O. similis* (ibid. fig. 10), four for *O. ferox* (ibid. fig. 12) and number five for *O. acer* and *O. dispar* (ibid. figs. 9 & 11), whereas in the new system of numbering (Mizelle, 1936) each anterior dorsal hook consistently becomes number seven for each species. Since the hooks involved (all except number one) are morphologically identical in structure with varying size relationships in different species together with the possession of variable linear relationships with each other, the stable character of ventral and dorsal distribution must be resorted to if any degree of regularity is to be attained. In the later proposed system of numbering (Mizelle, 1936) Mueller's starting point is utilized for hooks of the first pair but instead of zigzagging, in some cases, from one surface of the haptor to the other and in other cases, going consecutively from ventral to dorsal side with the exclusion of the hook pair in the region of the ventral anchors, the sequence is posteriorly around the ventral side of the haptor and then dorsally in an anterior sequence (Figs. 18-19). Hooks of pairs numbers six and seven always relate to those on the dorsal side of the haptor, number six being invariably the most posterior dorsal hook. The single pair of hooks whose position is in the region of the ventral anchors then obviously becomes number five in the new system instead of seven in that of Mueller's.

Mueller (1937) cited *O. mimus* and *Cleidodiscus robustus* as possessing the primitive hook arrangement whereas in 1936 he refers to *Actinocleidus oculatus* as possessing such. *A. oculatus* presents a specialized condition in which the bars are fused.

The present writer considers those species with the hooks distributed on both sides of the haptors as representing the primitive arrangement of these structures. Such *Tetraonchinae* are thought to have given rise to or to have had a common ancestry with the genera *Dactylogyrus, Gyrodactylus* and the specialized forms of *Tetraonchinae*. The species of *Dactylogyrus* described in this paper retain the distributional relationships of hook arrangement considered primitive for the *Tetraonchinae* and although the ventral pair of

anchors has disappeared, a ventral chitinous structure is present in *D. simplex*, *D. bifurcatus* and in many other previously discribed species. This structure could very easily be interpreted to represent a remnant of the ventral bar that once connected the two members of the pair of ventral anchors. In addition the genus *Haplocleidus* Mueller, 1937, which is characterized by a marked difference in the size of the two pairs of anchors, strongly suggests an intermediate stage in the transition from a condition of four anchors to a condition of two anchors or one pair. The genus *Gyrodactylus* is assumed to be more specialized than the foregoing since only one pair of anchors is present without a vestige of the ventral bar, oviparity is replaced by viviparity, eye spots have disappeared in adults and all the hooks (eight pairs) occur on the same side of the haptor.

The writer wishes to express his thanks and appreciation to Professor H. J. Van Cleave, Department of Zoology, University of Illinois for his encouragement and valuable suggestions; to Mr. M. S. Ferguson for calling the writer's attention to the gill parasites of the blunt-nosed minnow *(Hyborhynchus notatus)*; and to his wife for tabulation of data and typing of manuscript.

Type material of these three species of *Dactylogyrus* will be deposited in the U. S. National Museum.

REFERENCES

Bychowsky, B. 1929—Trematoden der Fische in der Umgebung der Stadt Kostroma. Trav. Soc. Nat. Leningrad **59**(1):3-27.

———1931—Neue Dactylogyrus-Arten aus dem Aralsee. Zool. Anz. **95**(10):233-240.

———1933—Beitrag zur Kenntnis neuer monogenetische Fischtrematoden aus dem Kaspisee nebst einigen Bemerkungen über die Systematik der Monopisthodiscinea. Fuhrmann, 1928. Ibid. **105**(2):2-37.

———1933a—Die Bedeutung der monogenetischen Trematoden für die Erforschung der systematischen Beziehungen der Karpfenfische. Ibid. **102**(9/10):243-251.

———1934—*Dactylogyrus cryptomeres* n. sp. und einige Bemerkungen über Monogenea aus dem See Beloje. Zool. Jahrb., Abt. f. System., Ökol. u. Geog. d. Tiere, **65**(2):193-208.

Diesing, K. M. 1858—Revision der Myzhelminthen. Sitzungsb. Akad. Wissensch. Wien., Math-naturw. Cl., **32**(23):307-390.

Goto, S. and H. Kikuchi. 1917—Two new trematodes of the family Gyrodactylidae. Jour. Coll. Sci. Imp. Univ. Tokyo Japan **39**:1-22.

Hughes, W. K. 1929—Some trematodes parasites on the gills of Victorian fishes. Proc. Roy. Soc. Victoria **41**(1):45-54.

Johnston, T. H. and O. W. Tiegs. 1922—New gyrodactyloid trematodes from Australian fishes together with a reclassification of the superfamily Gyrodactyloidea. Proc. Linn. Soc. N. S. Wales **47**(2):83-130.

Kulwiec, Z. 1927—Untersuchungen an Arten des Genus Dactylogyrus, Diesing. Bull. Acad. Polon. Sci. et Let., sér. B, **1927**:113-144.

LINSTOW, VON O. 1875—Beobachtungen an neuen und bekannten Helminthen. Archiv. Naturgesch. **41/1**:183-206.

———1878—Neue Beobachtungen an Helminthen. Ibid. **44/1**:218-244.

MIZELLE, JOHN D. 1936—New species of trematodes from the gills of Illinois fishes. Amer. Midl. Nat. **17**(5):785-806.

MUELLER, J. F. 1934—Additional parasites of Oneida Lake fishes, including descriptions of new species. Part IV. Roosevelt Wild Life Annals **3**(4):336-358.

———1936—Studies on North American Gyrodactyloidea. Trans. Amer. Mcros. Soc. **55**(1):55-72.

———1936a—New gyrodactyloid trematodes from North American fishes. Ibid. **55**(4):457-464.

———1937—Further studies on North American Gyrodactyloidea. Amer. Midl. Nat. **18**(2):207-219.

———AND H. J. VAN CLEAVE. 1932—Parasites of Oneida Lake fishes. Part II. Roosevelt Wild Life Annals **3**(2):79-139.

PRICE, E. W. 1937—North American monogenetic trematodes. I. The super-family Gyrodactyloidea. Jour. Wash. Acad. Sci. **27**(3):114-130.

WAGENER, G. 1857.—Beiträge zur Entwicklungs-geschichte der Eingeweidewürmer. Naturk. Verhandel. Holl. Maatsch. Wetensch. Haarlem.

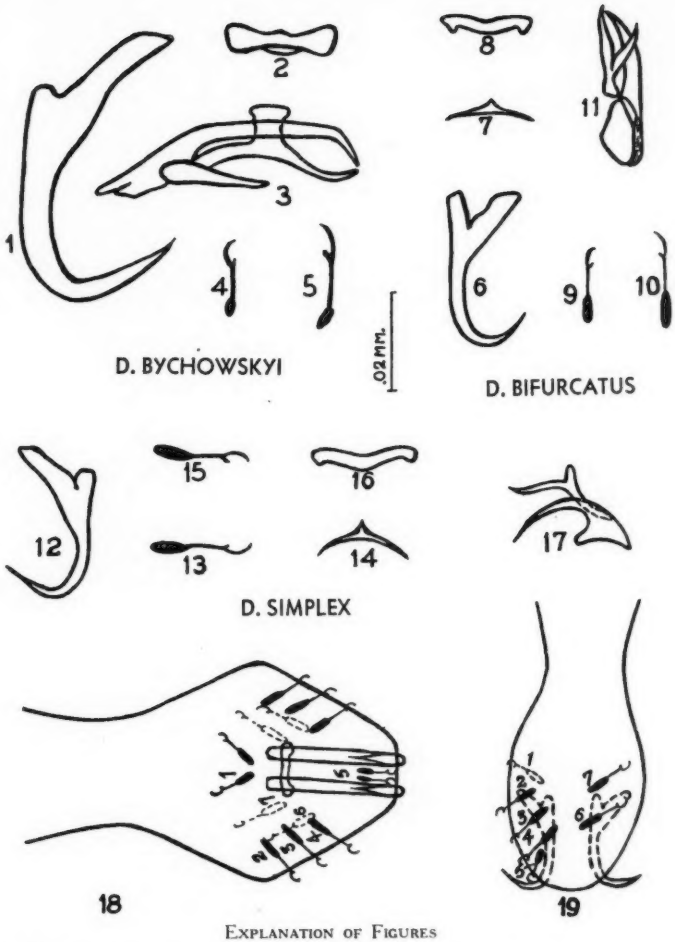
———1857a—Helminthologische Bemerkungen aus einem Sendschreiben an C. Th. v. Siebold. Zeitsch. wissensch. Zool. **9**(1):73-90.

WEDL, C. 1858—Anatomische Beobachtungen über Trematoden. Sitzungsb. Akad. Wissensch. Wien, Math.-naturw. Cl., **26**(1):241-278.

WEGENER, G. 1909—Die Ektoparasiten der Fische Ostpreussens. Schrift. Phys.—Ökon. Gesellsch. Königsberg **50**:195-286.

ZANDT, F. 1924—Fischparasiten des Bodensees. Ztbl. Bakt. u. Parasitenk. **92**(3/4): 225-271.

UNIVERSITY OF ILLINOIS,
URBANA, ILLINOIS.



EXPLANATION OF FIGURES

Each figure except nos. 18 and 19 were made to the same scale and with the aid of a camera lucida. Fig. 18 and 19 are enlarged diagrammatic drawings of haptors made at no specified magnifications.

Figs. 1-5. *D. bychowskyi*. 1, Anchor. 2, Dorsal bar. 3, Copulatory complex. 4-5, Hooks.

Figs. 6-11. *D. bifurcatus*. 6, Anchor. 7, Ventral bar or "Chitinklammer." 8, Dorsal bar. 9-10, Hooks. 11, Copulatory complex.

Figs. 12-17. *D. simplex*. 12, Anchor. 13-15, Hooks. 14, Ventral bar or "Chitinklammer." 16, Dorsal bar. 17, Copulatory complex.

Figs. 18, 19. Ventral and side views respectively of haptors to show hook arrangement.

The Genus Graminella (Homoptera-Cicadellidae)

Dwight M. DeLong and Carl O. Mohr

The genus *Graminella* DeLong was recently erected to include a group of small species which are common on fresh water marsh and salt marsh vegetation and a few of which occur on wet prairie grasses.

Two new species are described in this genus and ten previously described species are treated. The head, external male and female characters and, for the first time, the male internal genital characters are here described and illustrated. They will assist in a better understanding of the similarities and differences of these species. Since most of the species can be separated on the basis of color characters these are used in all possible cases in the following key but the genital structures will be of value in verifying the identity of the various species.

KEY TO SPECIES OF GRAMINELLA

1 Vertex, pronotum and scutellum with broad longitudinal red stripes 2
1′ Without red longitudinal stripes on vertex, pronotum and scutellum 4

2 (1) Vertex with a narrow black line on lateral margin, elytra with red longitudinal stripes ..... *texana*
2′ Vertex without marginal black line, elytra without red stripes 3

3 (2′) Four large black spots just above margin of vertex ..... *floridnana*
3′ Ocelli black and a pair of small black spots at apex of vertex ..... *aureovittata*

4 (1′) Vertex marked with two or more black spots or bars 5
4′ Vertex without black spots, sometimes with faint brownish markings 10

5 (4) Vertex marked with two broad black transverse bars which almost touch on middle line and are produced anteriorly to apex of vertex ..... *bisignata*
5′ Vertex marked with marginal spots, without transverse bars 6

6 (5′) Vertex with four marginal dark spots, outer ones at least, black, usually large, of about equal size, species northern in distribution 7
6′ Vertex with two or four marginal spots, but central spots, if black very small in size or if larger oblique in form and paler in color, not black, southern in distribution 8

7 (6) Size larger 4.5 mm. spots large, conspicuous, female segment with broad, median sunken tooth, male plates one half longer than combined basal width, apices pointed ..... *fitchii*
7′ Size not exceeding 4 mm. paler in color, ocelli black, spots often faintly marked, female segment concavely rounded without tooth, male plates as long as combined basal width ..... *pallidula*

8 (6′) Vertex wider between eyes than median length, apex rounded, spots at apex of vertex black and minute 9
8′ Vertex more strongly angled, as long at middle as basal width, ocelli

black, a large black spot anterior to each and a pair of oblique brown dashes at apex ---------- *nigrinota*

9 (8) Outer pair of spots on vertex large, pair at apex very minute, usually represented by a pair of black points ---------- *virginiana*

9′ Spots of vertex small and approximately same size. Ocelli black, of about same size and appearing as two additional spots ---------- *plana*

10 (4′) Male plates as long as combined basal width tapered to pointed apices, female with a round median tooth on last ventral segment, southern in distribution ---------- *albovenosa*

10′ Male plates decidedly shorter than combined basal width, apices more blunt, northern in distribution ---------- 11

11 (10′) Female segment with a prominent sunken tooth, apical portion of male oedagus concavely emarginate on ventral side before apex, large black tooth on upper apical portion ---------- *mohri*

11′ Female segment concavely rounded without tooth, male oedagus concave on dorsal surface, a small black tooth on ventral median portion ---- *oquaka*

Graminella pallidula (Osborn)

Thamnotettix pallidulus Osb. Proc. Ia. Acad. Sci. **5**:245, 1898.

A pale yellow species with six small black dots in a row above margin of vertex. Length 4 mm.

Vertex bluntly, rounded angled, one and one half times as wide between eyes at base as median length.

Color: Yellow, with faint ochraceous stripes, vertex with a row of six black dots, those at middle above margin and sometimes obsolete, the outer ones on margin anterior to eyes. Elytra pale brown or tawny, nervures paler, conspicuous.

Genitalia: Female last ventral segment with posterior margin broadly and deeply excavated, bearing an obtuse tooth at its apex. Male plates convexly narrowed to acute apices, styles broad with two anterior processes which are directed outwardly. Oedagus in ventral view tapered to bluntly rounded apex. In lateral view broad at base, tapered to a very narrow neck just before a rounded bulbous apex.

Originally described from specimens collected at Ames, Iowa. These have been used in the present study, but no other specimens are available.

Graminella mohri DeLong

Graminella mohri DeL. Ent. News **48**:50, 1937.

A yellowish blunt headed species without dark markings. Length 4 mm.

Vertex bluntly angled, about one-third wider between eyes than length at middle.

Color yellowish unmarked, veins of elytra not conspicuous.

Genitalia: Female last ventral segment shallowly, roundedly excavated on either side of broad, rounded median tooth. Central half of segment enbrowned. Male plates short and broad gradually narrowed to blunt apices.

Style rather narrow with a long basal process. Oedagus in ventral view broad at base slightly tapered to apical third then enlarged, apex bearing a broad deep U-shaped notch on either side of which is a blunt pointed apical process which is abruptly set off from body of oedagus at base. In lateral view the apical portion is constricted at base on ventral side then enlarged, apex broadly rounded, a large black spine on anterior apical margin.

Originally described from specimens collected at Presque Isle, Pennsylvania, Zion and Thomson, Illinois. These specimens have been used for this study.

Graminella oquaka DeLong

Graminella oquaka DeL. Ent. News **48**:51, 1937.

A pale yellow species with black ocelli. Length 4 mm.

Vertex bluntly angled, about one-third wider between eyes than length at middle.

Color yellow, ocelli black, indications of four very pale spots on margin of vertex. Elytra yellowish subhyaline, venation indistinct.

Genitalia: Female last ventral segment with central half of posterior margin broadly roundedly excavated about one-fourth the distance to base at the apex of which is a slightly produced broad median tooth. Male plates rather short, broad at base, rather gradually narrowed to acute apices. Style broad, the apical process long, curved outwardly. Oedagus in ventral view rather broad, slightly broader on apical third. Apex broadly deeply excavated by a U-shaped notch forming two diverse pointed apical processes which are broadened toward base and abruptly set off from body of oedagus. In lateral view the apical third is broadened, rounded on ventral surface, apex bluntly rounded, a black tooth on median ventral portion.

Originally described from specimens collected from prairie grasses at Oquaka, Illinois. The type specimens have been at hand for this study but no other records are available.

Graminella albovenosa (Sanders & DeLong)

Thamnotettix albovenosus S. & DeL. Proc. Ent. Soc. Wash. **25**:153, 1923.

A brownish species without dark marking on vertex. Length 3.5-4 mm.

Vertex bluntly angled, a little wider between eyes than length at middle.

Color: Pale brown, vertex with ocelli black and a pair of faint brownish spots at apex of vertex. Elytra brownish with pale nervures.

Genitalia: Female last ventral segment with short lateral margins then sloping to posterior margin which is faintly trilobate. Underlying membrane conspicuous at either side of segment. Male plates long, narrowed and tappered to long narrow apices. Oedagus in ventral view broad at base, tapered to a narrow slightly bifid apex. In lateral view broad on basal two-thirds then abruptly narrowed to form a long slender apical process.

Originally described from specimens collected at Paradise Key, Miami

and LaBelle, Florida. Specimens are also at hand from Gainesville, Florida, and a large series from Belle Glade, Florida.

Graminella texana (Osborn & Ball)

Athysanus texanus Osborn & Ball. Proc. Dav. Acad. Sci. 7:92, 1898.

Vertex obtusely angled, a little longer on middle than width between eyes. Length 4-5 mm.

Color: Vertex pale with a narrow black line on anterior margin, a pair of black spots above apex and a pair of broad, parallel longitudinal red stripes arising just back of margin and extruding across vertex pronotum and scutellum. Elytra with three pairs of red strips, the inner pair are a continuation of those on scutellum.

Genitalia: Female last ventral segment with posterior margin roundedly produced from near base the lobes of underlying membrane exposed at sides. Male plates rather long, sides gradually narrowing to acute tips. Male oedagus rather broad, slightly constricted at middle, apex with a deep and broad U-shaped notch, forming a pair of sharp pointed apical processes. In lateral view broad at base narrowly constricted just before apex which is slightly roundedly enlarged.

Known to occur only in Texas and Louisiana.

Graminella floridana sp. nov.

In general appearance and coloration resembling *aureovittata* but larger with more produced head and different markings. Length ♀ 4.5 mm.

Vertex broadly bluntly angled, almost rounded at apex, about one-fourth wider between eyes than length at middle, produced about one-third its length before anterior margins of eyes. Elytra long, greatly exceeding abdomen.

Color: Face pale, vertex yellowish with a row of four large black spots just above margin. The central pair are linear. A broad red band extends from apex of vertex to apical margin of scutellum either side of pale apex and does not cross basal angles. Elytra tawny in color, veins conspicuously pale.

Genitalia: Female last ventral segment with posterior margin truncate, central third broadly roundingly excavated and broadly margined with brown. Ovipositor brown.

Described from a series of seven female specimens collected at Belle Glade, Florida, during the summer of 1929 by Mr. Hugh Clifton. Holotype female and paratype females in collection of senior author.

Graminella aureovittata (Sanders & DeLong)

Thamnotettix aureovittatus S. & DeL. Penn. Dept. Agr. Bur. Plant Ind. Bul. 346, p. 16, 1920.

Vertex broadly rounded, one-fourth wider than long and only slightly produced before outer margins of eyes.

Color: Ocelli black and a pair of small triangular black spots at apex.

The two bright red longitudinal bands cover almost entire vertex on anterior margin but are narrowed on pronotum and scutellum. Elytra brownish with paler veins.

Genitalia: The female segment is rather deeply roundedly excavated on median half of posterior margin and brown bordered. The underlying segment shows conspicuously at lateral edges of last ventral segment. Male plates short and broad, rounded. Male oedagus in ventral view broadened at apex and narrowly notched. In lateral view it is tapered to a pointed apex.

Described from specimens from Big Bayou and St. Petersburg, Florida. Additional specimens are at hand from Paradise Key, Florida, Plymouth, Mass., and several localities in the Chicago Illinois area where it has been taken on the wet prairies.

Graminella plana (DeLong)

Thamnotettix planus DeL. Jour. N. Y. Ent. Soc. **32**:65, 1924.

A yellowish species with a row of four black spots on anterior margin of vertex. Length 3.5-4 mm.

Vertex bluntly angled, one-fourth wider between eyes than median length.

Color: Dull yellowish, ocelli black, a round spot next each ocellus and a pair back of apex, same size and shape, black. Elytra brownish, veins paler.

Genitalia: Female last ventral segment with lateral margins short, then produced to form a conspicuous rounded lobe either side of a broad sunken, truncated or slightly produced portion which is embrowned and occupies the median third of segment. Male plates short and broad, two-thirds as long as combined width at base, apices broad, bluntly rounded. Oedagus in ventral view broad, slightly constricted just before apical fourth which bears a broad, deep V-shaped notch forming a pair of pointed, divergent processes. In lateral view the oedagus is fairly broad on basal two-thirds, the apical third resembles *mohri* and *oquaka* and is broadened and broadly curved at apex.

Originally described from specimens collected at Miami, La Belle and Sanibel Id., Florida. One specimen is at hand collected at Brownsville, Texas, by Prof. Herbert Osborn.

Graminella bisignata (Sanders & DeLong)

Thamnotettix bisignatus S. & DeL. Proc. Ent. Soc. Wash. **25**:154, 1923.

Resembling *plana* in form and general appearance but with a broken black band across apex of vertex. Length 4 mm.

Vertex bluntly angled, a little broader between eyes than length at middle.

Color: Dull brown to yellow, vertex with two black transverse bars forming a broken band just above margin, the inner ends bent and extending anteriorly over apex on to front. Elytra pale to smoky, subhyaline. Face dark.

Genitalia: Female last ventral segment with posterior margin almost trun-

cate, slightly produced at middle. Male plates very long and narrow. Produced to form long, gradually narrowed pointed tips. Oedagus rather broad at base gradually tapered to bluntly pointed apex. In lateral view rather broad and uniform in width, slightly indented on ventral side near apex, with apical portion convexly curved on ventral side to form a pointed angle with the straight dorsal side.

Originally described from a single male from Cleveland, Florida. Dr. L. A. Stearns has recently found it occurring in abundance at lighthouses in Delaware Bay. It inhabits the salt marsh. Allotype female: Ship John Light House, Delaware Bay, Aug. 22, 1936.

Graminella virginiana (Sanders & DeLong)

Thamnotettix virginianus S. and DeL. Proc. Ent. Soc. Wash. **24**:99, 1922.

A blunt headed yellowish species with a row of four black spots on margin of vertex, the pair at middle are very small. Length 3.5-4 mm.

Vertex bluntly angled, almost rounded, a little wider between eyes at base than median length.

Color: Dull yellow, a large black spot just posterior to each ocellus, and a pair of very minute spots at apex, brown. Elytra pale brownish, veins white.

Genitalia: Female last ventral segment with posterior margin notched either side of a central, rather narrow, blunt embrowned tooth, produced at least one-third the length of the segment. Male plates rather short and broad, gradually narrowed from base to closely appressed blunt tips. Male style with a long tapered apical process. Oedagus in ventral view cleft at middle so as to form a pair of parallel processes which are widely separated, long, straight, and obliquely sloping at apex. In lateral view it is wide at base, the ventral side is extended into a long attenuated upwardly curved process, the dorsal portion tapers toward the ventral.

Originally described from specimens from Cape Charles, Virginia. Types were used during this study.

Graminella fitchii (Van Duzee)

Thamnotettix fitchii V. D. Ent. Am. **6**:133, 1890.

A large yellowish greenish species with four black spots above margin of vertex. Length 4.5 mm.

Vertex bluntly angled, slightly wider between eyes than median length.

Color: Yellow to dull greenish, with four black spots above margin of vertex, a round one next each ocellus and a pair of triangular spots just back of apex. Pronotum marked with five faint longitudinal striae. Elytra pale brownish subhyaline, veins pale.

Genitalia: Female last ventral segment roundedly excavated either side of a median slightly produced, broad, sunken tooth. Black markings of posterior margin causing it to appear more deeply notched. Male plates long, gradually, concavely tapered to bluntly pointed apices. Male valve with a

pair of processes on apex. Oedagus in ventral view broad, slightly constricted at middle and enlarged on apical third then tapered to a pair of out-turned pointed apical processes which are formed by a deep narrow median incision. In lateral view the oedagus is broad at base, narrowed near apex then appears enlarged by the curling of the apex.

This is the most common species of the genus and is found abundantly in fresh water marshes, swamps, rank growths of grasses and on the prairies. Specimens have been examined from a large number of states including Ohio, Pennsylvania, New York, New Jersey, Maine, New Hampshire, Virginia, Tennessee, Illinois, Wisconsin, Minnsota, Iowa and Kansas.

Graminella nigrinota sp. nov.

Resembling *albovenosa* in form and general appearance but with a large black spot next each ocellus, brown markings at apex, and with distinct genitalia. Length 3.5-4 mm.

Vertex bluntly angled, as long at middle as basal width between eyes.

Color: Face yellowish with paler arcs. Ocelli black, a large black spot just anterior to each ocellus and just above margin and a pair of proximal oblique brown dashes at apex of vertex. Pronotum scutellum and elytra yellow, mottled with white, veins of elytra pale.

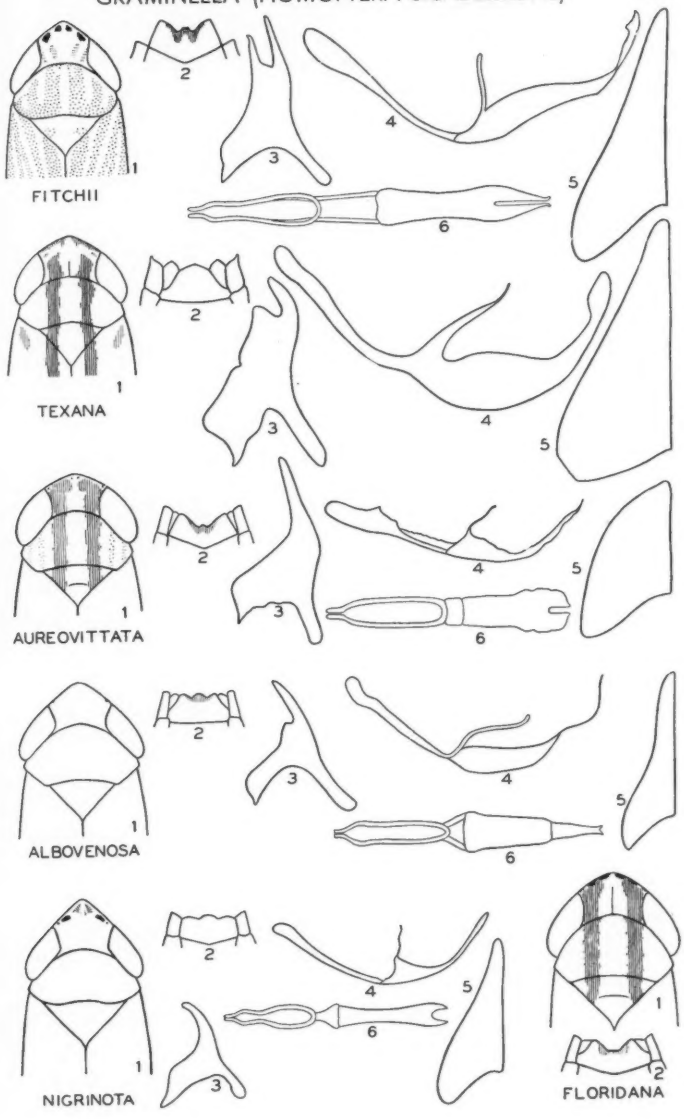
Genitalia: Female last ventral segment truncate with median third slightly produced, forming a broad rounded lobe. Male plates rather long, concavely narrowed to rather long, bluntly pointed apices. Male oedagus in ventral view short and rather narrow, slightly constricted at middle, enlarged at apex which bears a rather broad, short, U-shaped notch. In lateral view it is rather broad at base and tapered to a long attenuated apical portion with tip blunt. The style is short and broad with a short basal process, a broad body and a short curved apex.

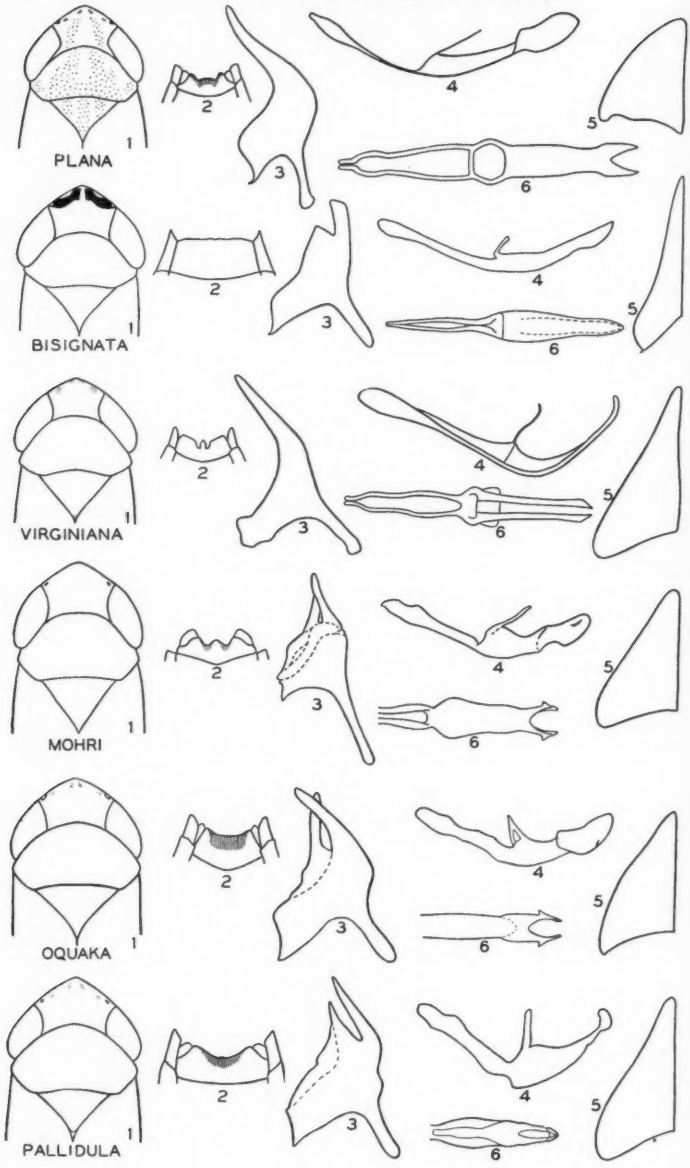
Described from a series of one male and eight female specimens collected at Florence, South Carolina, Sept. 1 to 20, 1930 by O. L. Cartwright, and one male from La Belle, Florida, collected April 21, 1921 by the senior author. Male holotype (Florida, female allotype (South Carolina) and male and female paratypes in collection of the senior author.

OHIO STATE UNIVERSITY AND
ILLINOIS NATURAL HISTORY SURVEY.

EXPLANATION OF PLATES

The name of each species is printed under the head (1). To the right of each head are: the female genitalia (2); male style (3); lateral view of oedagus (4); male plate (5); and ventral view of oedagus (6).


FITCHII
TEXANA
AUREOVITTATA
ALBOVENOSA
NIGRINOTA
FLORIDANA


PLANA
BISIGNATA
VIRGINIANA
MOHRI
OQUAKA
PALLIDULA
1
2
3
4
5
6

Evolutionary Trends, Ecological Notes, and Terminology of the Large-Winged Mites of North America

Arthur Paul Jacot

I. Introductory Note.
II. Evolutionary Trends
- Preview
- Movements
- Reductions
- Dis-synchronous Evolution
- Modifications of the Legs
- Pseudostigmatic Organs
- Ratio of Size to Egg Size
- Aparity
- Status of the tribe

III. Geographical Distribution.
IV. Habitat Relations
- Niches
- Food Habits
- Economic Importance

V. Systematic Notes
- Terminology
- Mounting Media
- Holotypes
- Chronological List of Earlier Species

VI. Literature Cited

Introductory Note

Detailed descriptions and figures of the species on which the present paper is based have already been published (29, 32-36). The bristles I call preanal and paranal are Grandjeans ad3, those I call lateral postanal are his ad2, and my mesal postanals are his ad1. In future, I will adopt his terminology for *these* bristles.

Evolutionary Trends

Preview

Morphological modifications, at least in the tribe Galumnini, may be grouped under three heads: developments, reductions, and movements. The most outstanding developments are those related to the wings. In the primitive genera the anterodorsal corner of this sclerotized leg cover is produced as a spur, while in the higher genera it is produced as a slender bar which pivots in the side of cephaloprothorax above the pseudostigmata. The wing itself is broader in the higher genera, and has a deep diagonal groove across its inner (mesal) face. This groove is gradually developed through one or two genera. Moreover a notch in the ventral edge of the wing is developed opposite the distal end of the groove. A further step in modification would be the extension of the groove through the outer face of the wing so as to divide the wing in two, and the modification of the wing muscles for flight.

Leaving the wing, one finds porose areas on the dorsal face of the notogaster in the higher genera though entirely lacking in the most primitive species. These porose areas are variously developed in the less primitive genera and become somewhat extensive in the highest genus (Galumna). Their function is unknown. They may be breathing pores. Grandjean has now shown this to be the case (49).

The ventral plate fits about the labium and mouth parts. In the primitive genera these anterior lobes are quite short and narrow. As the genera become more developed these lobes become broader until in the higher genera they are so expanded as to cover over the base of legs I and II.

The best example of a *reduction* is the lamellae. These are sclerotized blades which extend along the dorsolateral face of the cephaloprothorax. In the primitive genera these blades resemble a foot ruler placed on edge. In less primitive genera of the Galumnini they become less prominent, while in the more advanced they are appressed to the surface as thickened bands of the cephaloprothorax. In some species of the highest genus (Galumna) these bands slip down the face of the cephaloprothorax, while in two or three species they are entirely lost.

Another significant loss is the anterior edge of the dorsal shield (notogaster). As this is a modification of the midthoracic suture, its loss is the disappearance of the last vestige of segmentation on the dorsal face, and the most complete merging of cephaloprothorax with the post-thorax-abdomen. This loss also occurs in other unrelated tribes and subfamilies.

The bristles of the notogaster are present in a few of the higher species, though very minute. In all the other species they are marked by the insertions only. As a tribe these bristles are lacking, but retained in a few species.

The interlamellar bristles also become reduced in the more advanced genus Zetes, to lost in three or four species of Galumna. The reduction is by marked steps and not very gradually.

The tectopedial bristles are present in the primitive genera, and gone in the higher genera, at one leap.

The three pairs of sternal bristles are well developed in the primitive genera, vascilating in the more advanced genera, and entirely gone in some species of Galumna.

Of *movements* there are two types: the definitive (that is, those trending in a definite direction), and the indefinite or circumscribed. An example of definitive movement is the rostral bristles. These are inserted at the base of the rostrum, distant from edge of camerostome. Through the various genera they gradually migrate ventroposteriad to edge of camerostome, so as no longer to be visible from above.

Tectopedia I are sclerotized bands like the lamellae but lower down on the sides of the cephaloprothorax. These bands gradually move entad, disappearing entirely from the outer face and becoming prominent muscle insertion ridges inside the cephaloprothorax.

The middle bristle of parasterna I migrates anteromesad to a gular position, somewhat supplanting the first pair of sternal bristles (which, by this time, have become lost).

The paramesal bristles move from the primitive position midway between anal and genital apertures to a position posterolaterad of genital aperture and almost laterad of that opening.

An excellent example is the preanal bristles which migrate from the prim-

itive position anterior to anal aperture, *to* this opening, *down* its sides to the posterior corner, where they are blocked by the postanal bristles.

The primitive position of the genital aperture, as in all arachnoids is posterior to the legs. In the Galumnini, as in all winged mites, it is already between legs III and IV. In the highest Galumnini there is a further endeavor to locate itself between the *second* and third pairs of legs. This anterior migration of so large a body opening may be responsible for the movements of surrounding bristles.

Apodemata IV also move forward until quite close to the fused apodemata II-III, to which they become more or less attached.

The bristles I and 4 of the genital covers migrate from positions distant from the margins of the covers to positions on their anterior and posterior edges, so that these covers have only bristles 2 and 3 remaining on their face.

Similarly, the anterior anal cover bristles migrate to the anterolateral corner of the covers.

Although there are several examples of indefinite or circumscribed movements, I will give but two. The posterior anal cover bristles take up various positions in a circumscribed area, never approaching the edge of the cover.

The postanal bristles, which primitively were lateral in position, having reached their postanal position before the dawn of the tribe, are stopped by each other, and dance back and forth (their position constant within the species) behind the anal opening.

Reconsidering these changes, it will be evident that the three types of modifications presented (for the most part) take place at the same time and do not interfere with each other. Such changes are therefore synchronous, and harmonic to the organism as a whole. I have just enumerated twenty-one such modifications moving through eight genera. Such a progressive symphony of change is evolution.

The few indefinite or circumscribed movements are so limited as to take no part in the general movement. A mutation is a single modification. Here we do not have one modification per species but a combination of changes, each moving in a definite direction through several genera. What causes such a developing symphony of changes?

Size of Changes (mutations [?])

Among the Oribatoidea the mandibles are modified in three steps from what I take to be the primitive condition. This primitive mandible is a well developed, chelate organ, but not of heavy build. It is to be found in *Hypochthonius rufulus* and other primitive species. The distal end of the two digits slopes gradually down to the end. In the higher genera the end becomes much higher, almost squarish, giving it a more powerful appearance.

Specialization in the opposite direction, that is, by reduction and attenuation occurs in two distinct steps. First, in the genera Galumnopsis (16, p. 661, fig. 4), Pelops, and other unrelated genera, the mandible is drawn out

into a long arm and the biting surface is very much reduced, presenting an article similar to artery forceps (while the massive mandibles are more like tin-snips). The third step (Gustavia) brings about a loss of the moveable digit, with a further lengthening of the shaft, thus forming a piercing organ or stylet. No intermediate steps are known.

According to certain evolutionary ideas the intermediate steps formerly existed, but the species bearing them have died out. According to the mutation theory these steps are not needed. According to nature they do not exist.

Similar modifications are to be found in the length of body bristles. For instance, if one studies the interlamellar bristles one finds them: (1) minute and curved, (2) short (but longer than diameter of tarsi I) and straight, (3) of ordinary length, that is about the length of tarsi I, (3a) somewhat shorter is stout, (3b) somewhat longer is drawn out to a fine point, (4) very long, that is, two or three times length of tarsi I. The postanal bristles are similarly modified. They may be: (1) minute and curved (most Galumnini), (2) long enough to extend to end of ventral plate *(Protokalumma pterotum)*, (3) projecting distinctly beyond abdomen *(P. depressum)*, (4) very long and conspicuous *(Neoribates quadrisetosa)*. I find no intermediate steps, yet the two Protokalummas are so closely related as to interbreed in one part of their range (Florida).

Other instances of these mutational steps may be found, but the above will suffice. Total size of body is a good example. Most American Galumnini fall into three size groups: 0.3 mm., 0.5 mm., and 0.7 mm. The fluctuations are about these modes.

It therefore seems unnecessary to postulate minute intergradations in the origin or modification of all structural characters.

Movements

In evaluating the position of this tribe of the Oribatidae, and the various modifications that have taken place, I am using as a comparative basis three of the post primitive genera of the Oribatoidea, which have been worked out with some degree of detail,* namely Epilohmannia (40, p. 708, fig. 11). Collohmannia (41, p. 706, fig. 4) and Hypochthonius (mms). Of these I consider Epilohmannia most primitive because of the posterior position of the genital aperture, of the large genital plate, the large parasterna IV, and the freedom of the cephaloprothorax. Hypochthonius is more specialized in the enormous expansion of the anal plate (?) laterad and anteriad; while Collohmannia is more specialized in the anterior position of the genital aperture, restriction of the genital and anal plates and compression (elongation) of the abdomen.

The ventral face bristles of these genera may be tabulated as follows:

* Written in 1932, publication deferred until species were adequately described. Since this paper was written Grandjean has written several important papers on morphology and ontogeny of the Oribatoidea (17-24).

Primitive number of ventral face bristles

Parasterna I: 3 in all three genera
Parasterna II: 1 in all three genera
Parasterna III: 3 in Epilohmannia, 2 in others
Parasterna IV: 3 in Epilohmannia, 4 in Hypochthonius, 5 in Collohmannia
Genital plate: 3 in Epilohmannia, 2 in the others
Anal plate: 3 in Epilohmannia and Collohmannia, 2 in Hypochthonius
Genital covers: 3+5: 5+3 in Epilohmannia
5+5: 5+5 in Hypochthonius
0+8: 8+0 in Collohmannia
Anal covers: 3 in all

In the Galumnini these bristles are found in somewhat different positions and numbers. In order to understand these changes it is necessary to keep in mind the following correlation with the primitive bristles:
Parasterna I: I:1=sternal, I:2=major or gular, I:3=tectopedial
Parasterna II: II:1=sternal
Parasterna III: III:1=sternal, III:2=parasternal, III:3=tectopedial
Parasterna IV: IV:1=off apodemata II-III, IV:2=off apodemata IV, IV:3=tectopedial
Genital plate: only one (probably the mesal) is retained as paramesal
Anal plate: early found as postanals (ad1, ad2), with one pair (the mesal) as preanal or paranal (ad3).
Genital covers: early reduced to five and six
Anal covers: early reduced to two.

In studying the species and genera of this tribe the migrations and movements of these ventral plate bristles have led to the recognition of three types of changes which occur in various parts of the body. These can be tabulated as follows:

I. *Definite movements in one direction*

1. Migration of rostral bristles ventrad and posteriad.
2. Reduction of lamellae, from well defined projecting blades to appressed, straplike, structures curving downward and backward to ventral plate, and ultimately lost altogether.
3. Migration of tectopedia I from ectad to entad of cephaloprothorax.
4. Fusion of cephaloprothorax and notogaster, destroying the last vestige of somatic segmentation on dorsum.
5. Development of porose areas.
6. Gradual development of pteromorphal pivot.
7. Extension of ventral plate wings anteriad and laterad.
8. Loss of tectopedial bristles, which were the lateral bristles of the parasterna.
9. Migration of major bristle of parasterna I to gular position.

10. Progressive loss of sternal bristles, which were the mesal bristles of the anterior three parasterna.
11. Migration of paramesal bristles, from mesal position to near posterior corners of genital aperture.
12. Migration of preanal bristles, to posterior corners of anal aperture.
13. Shortening of sternal area (anterior migration of genital aperture [?]).
14. Progressive union of apodemata II-III with IV, especially at mesal end.
15. Progressive *reduction* of anterior corners of anal aperture.
16. Migration of genital cover bristles 1 and 4 to the anterior and posterior edges of the covers.
17. Migration of the anterior anal cover bristles to anterolateral corners of the covers.
18. Migration of subanal muscle plate from between the apertures to anterior end of anal aperture.

II. *Indefinite or circumscribed movements*

1. Lamellar bristles move laterad, ventrad or mesad.
2. Interlamellar bristles become *reduced* in various groups of species and in unrelated species.
3. Pteromorphal notch is sometimes anterior, sometimes ventral, and sometimes absent even in otherwise highly specialized species (Holokalumma).
4. Postanal bristles move back and forth behind the aperture without correlation and form two standard patterns: (1) subequally spaced, (2) grouped in two pairs.
5. Posterior anal cover bristle gyrates in its own definite orbit, trying out every possible position within a closely circumscribed area.
6. The marginal bristles of the genital covers are extremely stable. Only in the Hawaiian *Galumna swezeyi* do I find these bristles anteroposteriad of each other. This again is a highly specialized species which has retained this primitive character as well as all three sternal bristles.

III. *Retention of a primitive condition in a highly developed unit*

1. The notogastral bristles are already lost in the most primitive species and genera but retained, minute in size, in at least four species of the most specialized genus Galumna. See *G. curvum,* and in other countries *G. hungaricum* (39, p. 303, fig. 1), *G. alliferum* (37, p. 54, fig. 77), *Sandenia georgiae* (37, p. 75, fig. 100), and *Centroribates mucronatus* (37, p. 80, fig. 108).
2. Mesal position of paramesal bristles in Galumna.
3. Retention of some sternal bristles in some species of Zetes and Galumna, usually as insertions, sometimes in individuals of certain species.

From the above tables it will be seen that movements in a definite direction are the most numerous. As these movements are concurrent with each

other, and are definite, and in harmony with the general change going on in the group as a unit, I would designate them as *concurrent synharmonic changes*.

The second category contrast by not following the general theme of development. Each element appears in different places within a circumscribed area. An excellent example of this type is the two pairs of anal bristles which, having migrated from the sides of the aperture, are now stopped by each other in the narrow lane behind the anal opening and there they dance. These changes I would call *circumscribed movements* or changes. Finally, and fewest are those peculiar, moribund, primitive characters which have somehow been retained in a more or less vascillating condition along with the supremely progressive. These I would designate as *lags*.

Reductions

The presence or absence, especially the loss of bristles is worthy of special consideration. I have already pointed out that the members of the tribe as a whole do not bear notogastral bristles, only their insertions, but that there are at least five species in which they are present but minute. The tectopedial bristles are well developed in the three primitive genera and suddenly and completely lost in Zetes, Holokalumma and Galumna. The interlamellar bristles, one of the characteristic structures in the superfamily, become reduced to minute in size or are even lacking in unrelated species, say one in each section of Zetes, and in *Galumna flagelliferum* while well developed in the closely related *G. longipluma*. The sternal bristles are well developed in the three primitive genera. In Zetes, Holokalumma, and Galumna they appear as insertions and then only sporadically either in any one species or in individuals of a species. I have already referred to the appearance of three anal cover bristles instead of the typical and usual two (29, pl. 2, fig. 7) and pointed out that it is a reversion to the more primitive number (31, p. 376 Aberrations). In the Phthiracaridae there are as many as five and even eight, but in the majority of primitive Oribatidae there are but three. Finally in *Protokalumma depressum* and *Parakalumma robustum* the paramesal bristles are absent or represented by a scattered cluster of minute pseudoforamina. This then is another method of loss—by shattering or diffusion.

The lamellae are also gradually lost. In Protokalumma they stand out as bladelike ridges, the mesal edge being distinct even to the notogaster, in Neoribates the proximal end of the mesal edge is lost. In Zetes and Galumna the lamellae become still more reduced. In *Galumna virginiensis* the mesal edge has dropped half way across the frons. While in *G. alatum* and *G. longipluma* they are entirely gone.

Thus it will be seen that losses are gradual. If sudden, they may only have that appearance through lack of intermediate material. Reductions are typically synharmonic changes.

Dis-synchronous Evolution

One of the stamp-collecting systematist's greatest thorns is the impossi-

bility of arranging the species of a genus in a straight line of descent or even in a bifurcating series of lines.

This is due to the fact that any two characters which are regarded as of generic rank do not always make their appearance at the same time or in company with each other.

This is neatly illustrated in the genus Neorizetes. Here the lamellae are highly modified (as in Zetes) and tectopedia I are already ental (these may be mechanically correlated with the lamellae). On the other hand the pteromorphae do not have a transverse groove, but the ventral edge has a distinct notch. There are no developed porose areas. Another example is Holokalumma wherein the pteromorphae have no notch while all other characters are highly developed.

Similar examples are to be found among the species of any one large enough genus. Good examples are the sudden appearance of sculpturing. In *Z. weberi* the subspecies *Z. w. plumalae* has sculptured pteromorphae. *Z. emarginatus* is either a sculptured form of *Z. e. laevis* or vice versa. The sudden appearance (not in the Galumnini) of three in place of one hook on the unguis is another example. Dis-synchronous evolution is in fact a common zoölogical phenomenon which is due to the now well known law that unit characters are independent one from the other and likely to drop out at any time—provided that the presence of any one character is in harmony with the mechanics of the whole, or not lethal to the individual.

The term dis-synchronous evolution is therefore a term denying the old arboreal concept of evolution (the orderly appearance of characters) to the extent that some advanced structures will appear among a group of species (a genus) before it does in a related group (that is, before other structures which are related to it in more advanced genera, appear).

Dis-synchronous evolution is the appearance of any character independently of any other, or, more conspicuously, the appearance of some one character independently of some other (or others) with which it is always associated in another group.

Modifications of the Legs

In *Protokalumma depressum* the legs are stouter than in the other genera. The nubbin of tibiae I is more highly developed. The tendency has therefore been towards less power and more agility which would be expected of climbers. There has also been a reduction of bristles in femora I. For example, I find but one bristle on ventral face of femora I in the higher genera (except *Z. sinuofrons* from China). In Parakalumma and Neoribates there are two. The lateral bristle has either migrated to the dorsal edge or been lost in the higher genera. I say migrated to dorsal edge because in some species **Z. elimatus sinensis** comb. nov. (28, p. 122, fig. 5) and *Holokalumma coloradensis* (35, pl. 3, fig. 22) the dorsodistal is double. Parakalumma and Neoribates again are as in Protokalumma. In legs III and IV, *P. depressum* has a keel along ventral edge of femora. It also appears in Parakalumma and Neoribates but

is lacking in the higher genera. The bristles of trochanters IV and femora IV are of the same number throughout.

There is a greater difference between legs III and IV of any one species than between legs IV of all the species, or legs III of all the species. The chief interspecific difference in the leg bristles are in the relative lengths and armature of the bristles.

As to the tarsi and tibiae, one finds marked generic differences in specialization rather than reduction. This specialization is of two types: lengthening of bristles, the best examples being *Holokalumma lyricum* (35, pl. 3, figs. 27, 30) and *Galumna lanceatum octopunctatum* (33, pl. 10, figs. 7), and localization or concentration. The first type is dis-synchronous, having no correlation with other structures, the second is attained by a series of gradual changes. The best example is the group of bristles on the dorsoproximal half of tarsi I. In *Protokalumma depressum* there are three long ones and a minute one (32, pl. 8, fig. 5), in *Holokalumma coloradensis* there are two long and two minute (35, pl. 3, fig. 28), in *Zetes niger* there are two long and one minute (34, pl. 8, fig. 16) while in *Galumna lanceatum octopunctatum* there are two long ones, and two minute *insertions* crowded behind one of the long bristles (33, pl. 10, figs. 7, 9).

After looking over my work on the legs of this subfamily, beginning in 1922, I find that there are enough specific characters in the body to obviate the use of leg characters. I doubt if the legs of these species, if found separated from the body could be *specifically* determined (as in stomach contents work). But their detailed study is of phlogenic and evolutionary interest. Such study could best be done by using the legs of a standard species in each genus and comparing the legs of the other species of that genus with it. For this purpose the legs must be detached, mounted in true lateral and checked by dorsal aspects in whole mounts. There being so little interspecific difference I doubt there being any intraspecific variation. I have noticed none.

Pseudostigmatic Organs

Although pseudostigmatic organs occur in other Acarina they are standard equipment among the Oribatoidea and more highly developed than in any other group. In general it may be said that there is a tendency to lose these organs in aquatic species. Soil species tend to develop pectinate organs. Arboreal species tend to develop organs with large heads. There are no phylogenic trends in the development of these organs. They seem to be shaped chiefly by the environment and are therefore of ecologic significance.

In studying their shape it is imperative to examine them from all sides. An organ which is large and broad may be thin and fanlike. An organ may appear ciliate in one aspect and smooth in another. The length of the barbs may vary in different aspects. The number of pectinations (as in *Hypochthonius rufulus)* is greater in the right than in the left organ (of the same individual). See my remarks concerning the organ of *Zetes elimatus* (34, p. 53).

Ratio of Size to Egg Size

In the two smallest species *(Zetes minutus* and *Galumna curvum)* only two eggs are normally found, each occupying almost the entire side of the abdomen, leaving but very little space between them. In the advanced genera Zetes and Galumna, the average number of eggs is eight. *Parakalumma robustum,* with a maximum length of 0.9 mm., has a maximum capacity of twenty-four eggs.

That the size of the animal is not the determining factor is clear from the fact that the 0.7 mm. *Zetes elimatus* group bears as many eggs as the smaller (0.5 mm.) species, and that some of the medium sized species have a maximum of from four to twelve eggs. Eggs of primitive Galumnini are relatively smaller than eggs of advanced genera. Thus small, specialized species can have but few eggs, while large, more primitive species have a large number of smaller eggs.

Aparity

Aparity is that development in reproduction wherein the adult mother retains the eggs instead of laying them. The result is that the young hatch in the mother's body and are forced to feed on her tissues until they have eaten their way out. The larvae must cut through the tissues over and about the anal covers or the labium and mouth-parts (the genital aperture is too small for exit) in order to remove these structures. The anal covers can open outwardly only.

The reason for this phenomenon is that the size of the eggs in this tribe increases as the species become more specialized. This means that in *Z. minutus* and *G. curvum* each egg occupies one-half of the abdomen. As the ovipositor and genital aperture retain the same proportion relative to the rest of the body, and as the body is so highly and completely sclerotized as to form a non-yielding aperture, the relatively huge eggs, in order to be evacuated, must be compressed to form a long tube or stay within the mother to hatch. Viviparity is known in this family in the intertidal genus Ameronothrus. Short of viviparity, aparity must result. Aparity is common to various genera of winged mites outside the Galumnini. For further details on this subject see paper 32a.

Status of the Tribe

Besides the eight North American genera, Centroribates (7, p. 122), Sandenia (37, p. 74), Galumnella (8, p. 58) and Galumnopsis (16, p. 661) have been recognized. Throughout these genera there is so much uniformity of structure that the group is unmistakable. There are no links with the past. So much is this the case that I am unable to determine from what primitive oribatids the Galumnini have sprung.

Geographical Distribution

The Galumnini of North America, as far as now known, show great affinity to Eurasia and very little to South and Central America.

One of our species *(G. curvum)* is also found from north China to the East Indies but not in Europe. *Parakalumma robustum* has a closely related species *(P. lydia)* in north China. No other species of this genus are known. These are therefore examples of the peculiar distribution which may be known as *Appalachi-sinian*. The genera Liriodendron and Cryptobranchus-Megalobatrachus are well known examples.

One species of Neoribates *(N. roubali,* 6, p. 385) is found in Europe, but the descriptions are so meager as to make comparisons impossible.

One European species of Protokalumma *(P. aurantiacum* 37, p. 16) is very close to *P. depressum.*

Neorizetes, Holozetes and Holokalumma have not yet been reported from Europe or Asia.

Zetes nervosus and *Galumna longipluma* are certainly recent introductions in America because they are found chiefly about our cities, and have no subspecies in America. This brings us to a definite criterium for the recognition of introduced species, that is the formation of subspecies.

One of the well known phenomena of geographical distribution is that of geographical races. All the indigenous North American mammals and birds of wide distribution have become locally differentiated as subspecies. The house sparrow, house mouse, german cockroach and other introduced species do not enjoy, to date, this geographical differentiation in our country. It may therefore be postulated that North American species which are represented by subspecies (geographical races) were indigenous to America before the unloading of the Mayflower.

Galumna alatum with at least three American subspecies, is therefore indigenous, certainly not recently introduced. There is an appreciable though slight difference between our specimens of *G. alatum* and those from Bavaria. Due to the lack of detailed studies in Europe, I am unable to tell if this difference represents a European race.

Galumna lanceatum octopunctatum is represented in western Europe (from Strasbourg southward) by a subspecies. I originally considered these two races as identical, but Grandjean's detailed figures (58, figs. 12, 13) show the American form to differ in position of adalar bristles, genital cover bristles 2, paranal bristles, and anal pseudofissurae. There also seems to be a difference in extent of ventral plate wings. It thus appears that *G. octopunctatum* is a distinct species closely related to *G. lanceatum.*

Zetes elimatus ithacensis, and *Z. e. louisianae* are American subspecies of a European species. After the Europeans have made a careful study of their material, comparing extensive series of Scandinavian, central European and circummediterranean specimens, we will be better able to tell if *Z. elimatus ithacensis* is an introduced subspecies or a native of North America. The specimens of *Z. elimatus* from California are certainly recently introduced.

Habitat Relations

NICHES

In determining the habitat of these species, the lots yielding most specimens are used. Lots yielding but one or two specimens are regarded as accidental or not typical and therefore of no value as indicators of habitat *preference*. It follows that species collected only a few times can yield no certain habitat data.

The most outstanding habitat difference evident from the above data is the subaquatic habits of *G. alatum* in Europe, and the dry habitat of the race from the northeastern states, being found in litter on top of Wachusett mountain, from old fence rails, chips of wood, and such, in an orchard and in a pasture, and so on. Here is an example of change of habitat to usher in isolation, the originator of morphological species.

The group is primitively one of the forest floor but it has radiated from this by developing a new habit, namely climbing, instead of snuggling. The result is that many of the species ascent vegetation, including trees. It is accidental in sphagnum moss of open bogs.

Woody fungi of the middle west seem to be the choice habitat of *Neoribates quadrisetosus*. Grass sod is the almost exclusive habitat of *Zetes graminetum*.

Zetes emarginatus seems to be a general dweller (ecological wide). I have taken it in numbers from epigeous moss; on stones in a wet meadow, eating algae (?); on rotten wood. The great preponderance of records are from old and decaying wood. Many lots from moss yield large numbers of *Galumna octopunctatum* and few *Zetes emarginatus*. Those moss lots which have yielded fair numbers of *Z. emarginatus* may have been on decayed wood. Whether in moss or decaying wood we do not yet know *why* it is there, what food it seeks. It is the most common species of the northeastern states.

G. octopunctatum is the outstanding moss species both in the northeastern states and about Strasbourg (Alsace). It is even found in sphagnum.

G. alatum prefers decaying leaves to decaying wood.

List of Niches and their Galumnin Fauna

Decaying Wood
Protokalumma depressum
Protokalumma pterotum
Zetes niger
Z. emarginatus
Z. nervosus
Galumna virginiensis
G. longipluma

Decaying Leaves
Parakalumma robustum
Z. climatus ithacensis
Z. alatum

Sod
Z. graminetum
G. virginiensis

Moss
Z. emarginatus
Z. nervosus
G. octopunctatum
G. longipluma (Eu.)
G. curvum

Woody Fungi
Neoribates quadrisetosus

Tussock Sedge
Galumna curvum

Trees
Z. arborea
G. banksi
G. curvum

Food Habits

Although it is usually impossible to determine the feeding habits of Oribatids by direct observation, I am able to say positively that *G. virginiensis* eats fungal spores, *G. banksi* at least at times, while *G. octopunctatum* seems to feed on algae.

One lot of *Z. emarginatus* I found lined up around a stone, just above the waterline formed by lying on a seepage wet hill slope. This waterline was also the algal line. I saw a similar instance in the woods north of Strasbourg. Here on a huge oak was an oval scar where the bark had been removed, leaving the flat, smooth wood. A crescent on the lower part of this oval was green with algae, as it had rained during the previous day and the trunk was drying. The upper part of this green algal crescent was lined with *Oribatella calcarata* and a few *Xenillus tegeocranus*. They were working downward following the retreating moisture and algae. This combination of observations leads me to state that Oribatid mites are to an unknown extent feeders on algae as well as on minute fungi.

Economic Importance

Those species which eat fungal spores may be instrumental in dissemination of the fungus, as I have already recorded in detail elsewhere (30).

Systematic Notes

Terminology

In order to describe the various parts of these highly complex though minute organisms it is necessary to give names to the parts. Although this has already been done in scattered papers it has not been done thoroughly and conveniently. As I have had to introduce a few terms, I take this opportunity of presenting as complete an index of terms for this group as possible.

Bilateral orientation is referable to the median plane, represented by the black line in the figures. *Mesad* means towards the median plane, *mesal* is on the median plane side of any member; *laterad* means away from same. For example, a mesal bristle on the tibia is situated on the median plane side of the tibia when the leg is normally held parallel with the median plane. A lateral bristle on that tibia is situated on the opposite side of that segment. *Proximad* means towards the center of the body, *distad* away from that center. *Remote* and *approximate* refer only to the members of a pair. The members of a pair are always separated by the median plane. No two bristles on the same side of the median plane comprise a pair.

Roman numerals standing alone are used exclusively to designate one of the four pairs of legs, or structures related to these four pairs, beginning with the anterior one. For instance, apodemata II-III means, the fused apodemata of the second and third pairs of legs. Non-median structures are given in the plural form (since there is always a duplicate on the other side of the median plane). Roman numerals may be used to designate bristles of the hypothetical or known abdominal segments only when coupled with an arabic numeral designating the bristle's position relative to the median plane. For example

NII3 means, notogastral bristles of the second abdominal segment, third removed from the median plane (that is, in the third longitudinal row). Serially numbered bristles are numbered from the proximal end to the distal end, or from the median plane to the lateral extremity of that structural unit. My present concept of the notogaster is that it comprises fused thoracic tergites III, IV and the abdominal tergites.

The word *bristle* is often used in refering to its *insertion,* as it is, in this group, usually much easier to see the insertion than the bristle when minute. The term pseudoforamen has been used for small clear spots (like pin pricks) in the body wall, especially in the notogaster. A careful comparison of the situation of these spots in my various figures will show them to be fairly constant in position from species to species. A further comparison with the figures of the species bearing minute bristles on the notogaster as *Galumna curvum* (33, pl. 12, fig. 26), *G. hungaricum* (39, p. 303), *G. alliferum* (37, p. 54, fig. 77), *Sandenia georgiae* (37, p. 75, fig. 100), will show that some of these pseudoforamina are bristle insertions. Consequently those which are, from these figures, definitely known to be insertions will be referred to under that term (I have dropped the term puncture), restricting the term pseudoforamen to those spots which are not positively known to have been occupied by bristles, as the sievelike group in the notogaster of *G. longipluma* males. The most complete illustration of these bristles is that of *G. hungaricum,* where there are nine on each side and one on the pteromorpha, totaling 20. This also agrees with Grandjean (25, figs. 12). Bristle insertions sometimes

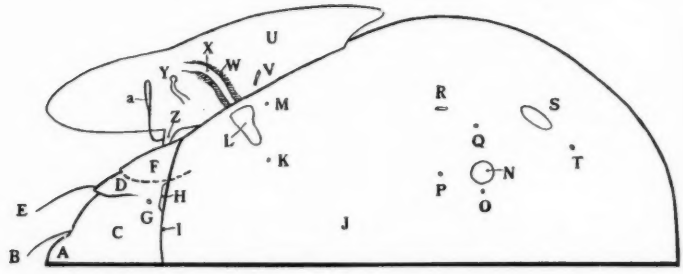


Fig. 1. Dorsal aspect. A= rostrum, B=rostral bristle, C=cephaloprothorax: composed of frons (anterior to the C) and vertex (posterior to the C), D=lamella, E=lamellar bristle in primitive position. When *lateral* it is inserted more posterolaterad, *peripheral* on mesal rim of the lamella, *frontal* when inserted mesad of mesal rim. F=shadow of tectopedium I, G=interlamellar bristle insertion, H=anterior porose area, I=abdominocephaloprothoracic or midthoracic suture, J=notogaster, K=mesal adalar insertion, L=adalar porose area, M=posterior adalar insertion, N=mesal mesonotal porose area, O=mesal mesonotal insertion, P=anterior mesonotal pseudoforamen, Q=lateral mesonotal insertion, R=mesonotal pseudofissura, S=lateral mesonotal porose area, T=posterior mesonotal porose area, U=pteromorpha, V=pseudofissura, W=posterior rib of: X=groove (on ventral face of pteromorphae), Y=insertion, with its channel (also on ventral face), Z=pivot (pteromorphal), a=pseudostigmatic organ.

appear double (as in *Protokalumma depressum*) or with a comet-like tail. This tail I call the *channel* as it is a channel through the body-wall for the passage of the nerve and other tissues. The body-wall is so thick that bristle channels through it, appear quite long when they traverse the wall obliquely to the surface. The doubleness of an insertion is due to the inner and outer openings of the channel, especially when the channel does not traverse the body-wall at right angles to the surface.

A bristle may be *burred, barbed,* or *ciliate* (33, pl. 11, figs. 22, 21 and 20) or *pectinate* (the cilia being thick and stiff like the teeth of a comb). A *pauciciliate* bristle is one bearing three or four ciliary appendages, a *multiciliate* bristle bears seven or eight cilia. For the terminology of the leg bristles see *Zetes niger* (34).

In the figures, a broken line indicates an internal structure, a dotted line an internal structure at a still deeper (more internal) level.

The posterior porose areas and the pseudoforamina along ventral portion of notogaster are not recorded in this revision as they are not of *practical* value in the identification of species. There is a median porose area on posterior edge of ventral plate in some species, but it is only visible when the specimen is placed on its rostrum. The genital and anal aperture *frames* are caused by the extension of the edges of these apertures ventrad.

Thinly sclerotized species have primitive structures more distinct (as abdomino-cephaloprothoracic suture, lamellae fused to cephaloprothorax as in *G. alatum,* sternal and other bristles, veins of pteromorphae). These struc-

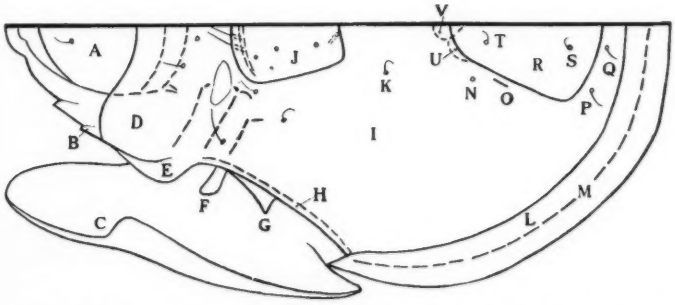


Fig. 2. Ventral aspect. A=labium, B=ventral edge of tectopedium I, C=notch in pteromorpha, D=wing of ventral plate, E=tectopedium II, F=tectopedium III, G=tectopedium IV, H=ventral edge of leg cupboard (joining ventral plate), I=ventral plate, J=a genital cover, K=paramesal bristle, L=ventral edge of notogaster (which clips over edge of ventral plate), M=edge of ventral plate, N=paranal bristle (when anterior to anal aperture it is called the preanal bristle), O=pseudofissura (of anal aperture), P=lateral postanal bristle, Q=mesal postanal bristle, R=an anal cover, S=posterior (anal) cover bristle, T=anterior (anal) cover bristle, U=internal angle (of anal aperture), V=subanal muscle plate.

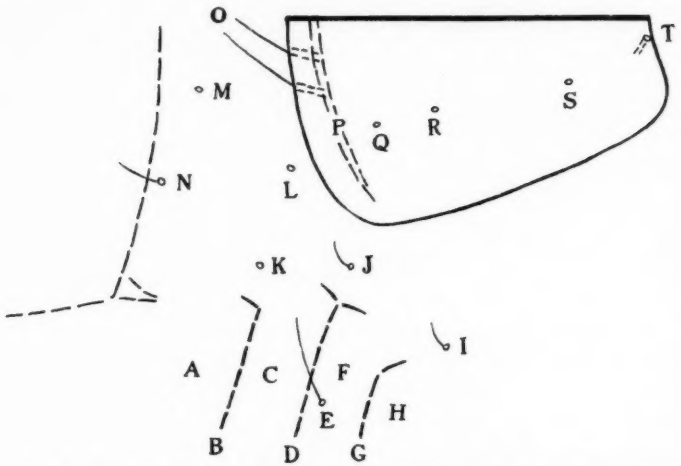


Fig. 3. Genital area. A=parasternum I, B=apodeme I with one *ceriph*. Apodemata are figured as seen in ventral aspect by transmitted light and not merely the portion actually attached to the ventral plate which is usually a smaller portion than is figured. C=parasternum II, D=apodeme II-III with two ceriphs, E=parasternum III, F=bristle of parasternum III, G=apodeme IV, H=parasternum IV, I=bristle off apodeme IV, J=bristle off apodeme II-III, K, L, M=sternal bristles 2, 3, 1 (respectively), N=gular bristle (=bristle of parasternum I), O=marginal bristles (of genital covers) with their channels, P=ridge (ental), Q=genital cover bristle 1, R=genital cover bristle 2, S=genital cover bristle3, T=genital cover bristle 4 with its channel.

PLATE 1

Zetes emarginatus

FIGURES

1. Outline of posterior edge of genital covers with ovipositor beneath; ratio x 330.
2. Posterior half of genital covers with penis beneath; ratio x 330.
3. Pseudostigmatic organs bearing a parasite on distal end; ratio x 440.
4. Ovipositor, showing central bristle ring, and the pair of bristles of the ventral lobe; ratio x 440.

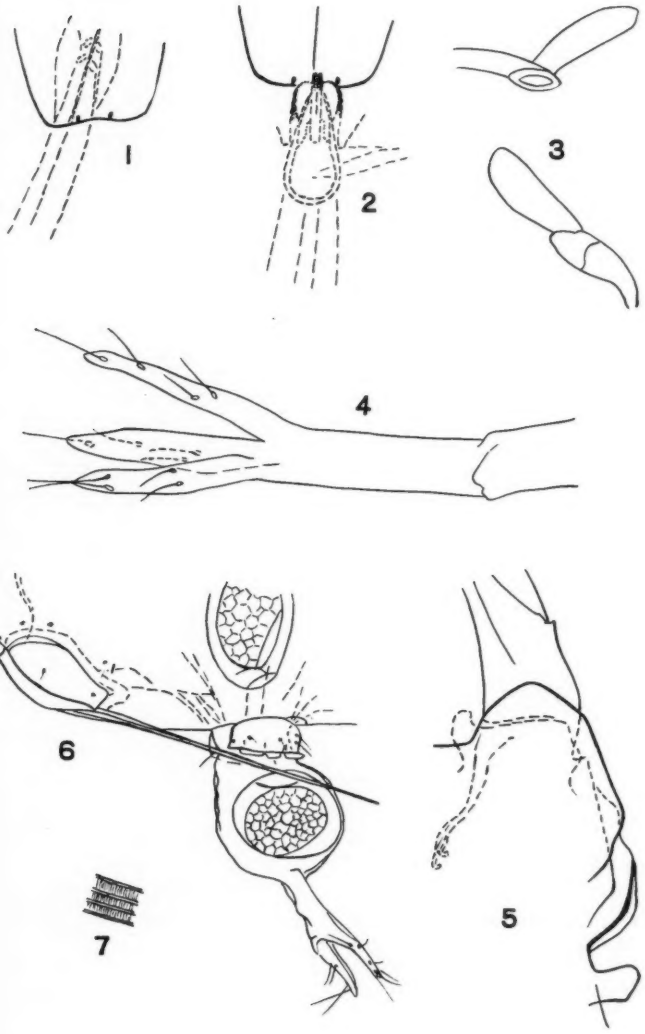
Calumna alatum hispidum

5. Oviposition; egg in ovipositor, spermipositor extending from anterior end of anal aperture; ratio x 100.
6. Spermipositor, section at proximal third; free hand.

Zetes niger

7. Ventral plate wing with tectopedia II showing posteriad and beneath it; ratio x200.

PLATE 1



tures are lost as the sclerotization becomes thicker (more dense, more darkly colored).

Extra bristles are sometimes found, as sternal bristles in species in which they are usually absent, or three bristles on each anal cover, and so on. These are reversions and not indicators of a new species!

The proximal end of the femur, I regard as including a trochanter. What has usually been referred to as a *coxa,* I believe to be, and call, a *trochanter.* The coxa is internal. For details of these structures see paper 31a.

In determination of sex, three characters may be relied on: presence of eggs (seen by transmitted light) in season, extruded ovipositor (when animals are killed with boiling water), or inspection of sex organs by strong transmitted light. The three pairs of suckers, three on the inside of each genital cover, are present in both male and female. The tip of the ovipositor is usually above and cephalad of the center of the genital covers when closed, while the male organ is located above and to the rear of the posterior edge of these covers. Furthermore, the ovipositor is much more slender at the tip than the male organ and its lines are much more attenuated than those of the male organ. Plate 1, Fig. 1 gives the appearance of the ovipositor closed up beneath the covers, while figure 2 gives the appearance of the male organ in one position. The collar about the centrodistal points seems to be a flap or cover. Before the points enter the bulb which is situated at their base, they are encircled by a collar (seen in section in the figure). In mounted specimens, this bulb, the points and the edges of the cover, are the prominent parts which make a characteristic pattern, differing strikingly from the slender. elongated, tapering lines of the distal end of the ovipositor. We have yet to see one extruded and expanded. The ovipositor lies along or near the ventral plate while the penis is nearly vertical in position.

In recording the number of eggs only those distinctly discernible and well formed are counted.

Mounting Media

I have used three mounting media. The gum arabic (Berlese-Faure) medium was found to contract a great deal in drying thus causing air bubbles under the cover-glass. These were difficult to eliminate because of the viscidity of the gum which did not flow readily into the bubbles. A great deal of time was wasted in this supplementary filling which has to be repeated even two years after mounting.

The same difficulty was experienced with Euparal. But the greatest drawback to its use is that even after the animals are cleared, they remain quite dark.

Balsam on the other hand flows easily, and does not contract as much, so that bubbles are found only in mounting with very thin balsam. Best of all, material that has been mounted in balsam is quite transluscent and in mounts fifteen to twenty years old the specimens are so clear that many internal organs and muscles as well as tracheae can be seen.

The chief objection to balsam is that it is so refractive that fine structures

like cilia of bristles become invisible. These structures are still there, and with proper lighting conditions can be resolved.

Holotypes

As it is almost impossible to draw up a satisfactory description on one individual, and as most of my figures are based on more than one individual, I have no idea which specimen should become a holotype. Furthermore as most lots comprise several specimens taken from the same handfull of moss or an area of a few square inches of surface, that is probably all F_2 or F_3 relations, designating the lot as cotypes approximates natural conditions more than singling out an arbitrary individual to call it a holotype.

Chronological List of North American Galumnini

Oribata alata (38, p. 42, pl. 11, figs. 2, 2a) not Schrank; nomen nudum
Oribata depressa (1, p. 6) is *Protokalumma depressum* (Banks)
Oribata robusta (1, p. 7) is *Parakalumma robustum* (Banks)
Oribata emarginata (1, p. 7) is *Zetes emarginatus* (Banks)
Galumna texana (2, p. 494, pl. 17, fig. 24) is *Holozetes texanus* (Banks)
Oribata curva (10, p. 113, pl. 14, figs. 5, 6) is *Galumna curvum* (Ewing)
Oribates centropterus (5, p. 6) is *Parakalumma robustum*
Oribates tantillus (5, p. 7), is *Galumna curvum*
Oribata emarginata (12, p. 355; 6, p. 56) is *Z. corrugis milleri* Jacot
Oribata robusta (12, p. 355; 18, p. 121) is *Neoribates quadrisetosus*
Oribata octopunctata (12, p. 356, pl. 34, fig. 7) is *G. octopunctatum* (Ew.)
Oribata nigra (11, p. 119, pl. 2, fig. 6) is *Zetes niger* (Ewing)
Oribata macroptera (11, p. 120, pl. 2, fig. 7) is *Zetes macroptera* (Ew.)
Oribata rugosala (11, p. 120, pl. 3, fig. 8) is *Neorizetes rugosala* (Ew.)
Oribata minuta (11, p. 121, pl. 3, figs. 9, 10) is *Zetes minutus* (Ewing)
Galumna pterota (3, p. 8, pl. 2, fig. 20) is *Protokalumma pterotum* (Banks)
Oribata depressa (13, p. 97, pl. 6, fig. 29) is *Protokalumma depressum*
Oribata texana (13, p. 99, pl. 6, fig. 31) is not Banks
Oribata setiformis (26, p. 506, fig. 163) is *Galumna longipluma* (Berlese)
Oribata humida (27, p. 642, fig. 212) is *Zetes humida* (Hall)
Oribata alata californica (27, p. 643, fig. 213) is *Gal. californica* (Hall)
Oribates salicis (14, p. 117, pl. 8, fig. 11) is *Protokalumma salicis* (Ew.)
Oribates corticis (14, p. 117, pl. 8, fig. 12) is *Protokalumma corticis* (Ew.)
Oribates emarginatus (7, p. 125, pl. 1, fig. 14) is *Gal. octopunctatum*
Oribates nervosus (7, p. 127, pl. 1, fig. 15) is *Zetes nervosus* (Berlese)
Oribates (Neoribates) robustus (7, p. 128, pl. 2, fig. 21) is *Parakalumma robustum*
Oribates (Neoribates) fissuratus (7, p. 128, pl. 2, fig. 22) is *Protokalumma fissuratum* (Berlese)
Galumna acutifrons (4, p. 61, fig. 1) is *Zetes acutifrons* (Banks)
Oribates cribriger (9, p. 306) is *Galumna cribriger* (Berlese)
Oribates emarginatus columbianus (9, p. 306) is *Zetes emarginatus*
Oribata quadrisetosa (15, p. 161, pl. 3, fig. 42) is *Neoribates quadrisetosus* (Ew.)
No other records appear until 1929 (29).

LITERATURE CITED

1. Banks, Nathan. 1895 (Jan.)—On the Oribatoidea of the United States. Trans. Am. Ent. Soc. **22**:1-16.
2. Same. 1906 (Nov.)—New Oribatidae from the United States. Proc. Acad. Nat. Sci. Philadelphia **58**:490-500, pls. 14-18.
3. Same. 1910 (Jan.)—New American Mites. Proc. Ent. Soc. Washington **12**:2-12, pls. 1-3.
4. Same. 1915 (April)—Two Mexican Myremecophilous Mites. Psyche **22**:60-61, figs. 1-2.
5. Berlese, Antonio. 1908 (August 5)—Elenco di Generi e Specie nuove di Acari. Redia **5**:1-15.
6. Same. 1910 (July 8)—Brevi Diagnosi di Generi e Specie nuovi di Acari. Redia **6**:346-388.
7. Same. 1914 (Dec. 31)—Acari nuovi, Manipulus IX. Redia **10**:113-150, pls. 1-4.
8. Same. 1916 (June)—Centuria prima di Acari nuovi. Redia **12**:19-67.
9. Same. 1916 (Dec.)—Centuria terza di Acari nuovi, Redia **12**:289-338.
10. Ewing, H. E. 1907 (Dec.)—New Oribatidae. Psyche **14**:111-1115, pl. 3.
11. Same. 1909 (Oct. 8)—New American Oribatoidea. Jour. N. Y. Ent. Soc. **17**: 116-136, pls. 2-6.
12. Same. 1909 (Sept.)—The Oribatoidea of Illinois. Bull. Ill. State Lab. Nat. Hist. **7**:337-390, pls. 33-35, 5 txt. figs.
13. Same. 1910 (March 1)—A Systematic and Biological Study of the Acarina of Illinois. The University Studies **3**, as part of the Univ. Ill. Bull. **7**(14): 120 pp. 8 pls., 6 txt. figs.
14. Same. 1913 (May 31)—New Acarina, Part I. Bull. Am. Mus. Nat. Hist. **32**:93-121, pls. 7-8, 9 txt. figs.
15. Same. 1917 (Jan. 27)—New Acarina, Part II, same, **37**:149-172, pls. 1-4.
16. Grandjean, F. 1931 (March 19)—Observations sur les Oribates (1re Série). Bull. Mus. nat. d'Hist. nat. Paris, sér. 2, **3**:131-144, 4 comp. figs.
17. Same. 1933 (March 31)—Étude sur le Développement des Oribates. Bull. Soc. zool. France **58**:30-61, 27 figs.
18. Same. 1933 (April 19)—Observations sur les Oribates (4e Série). Bull. Mus. nat. d'Hist nat. Paris, sér. 2, **5**:215-222, 3 figs.
19. Same. 1933 (Dec. 26)—Same, (5e Série). Same: 461-468, 4 figs.
20. Same. 1934 (Nov. 27)—Same, (7e Série). Same **6**:423-431, 4 figs.
21. Same. 1934 (March 31)—La Notation des Poils gastronotiques et des Poils dorsaux du Propodosoma chez les Oribates (Acariens). Bull. Soc. zool. France **59**:12-44, 10 comp. figs.
22. Same. 1934 (March 31)—Les Organes Respiratoires Secondaires des Oribates (Acariens). Ann. Soc. ent. France **103**:109-146, 17 comp. figs.
23. Same. 1935 (Jan. 18)—Les Poils des Épimères chez les Oribates (Acariens). Bull. Mus. nat. d'Hist. nat. Paris, sér. 2, **6**:504-512, 3 comp. figs.
24. Same. 1935 (April 15)—Les Poils et les Organes sensitifs Portés par les Pattes et le Palpe chex les Oribates. Bull. Soc. zool. France **60**:6-39, 8 comp. figs.
25. Same. 1936 (May 30)—Les Oribates de Jean Frédéric Hermann et de son Père. Ann. Soc. ent. France **105**:27-110, 14 comp. figs.
26. Hall, H. V. M. 1911 (May)—Studies in Acarina I. Pomona Jour. Ent. **3**:504-510, txt. figs. 161-165.
27. Same. 1911 (Dec.)—Same II. Same: 641-648, txt. figs. 211-216.

28. JACOT, A. P. 1922 (Oct.)—Oribatoidea Sinensis I. Jour. N. China Branch R. Asiatic Soc. **53**:118-130, 19 txt. figs.

29. SAME. 1929 (Jan.)—American Oribatid Mites of the Subfamily Galumninae. Bull. Mus. Comp. Zoöl. **69**:3-37, pls. 1-6, 1 txt. fig.

30. SAME. 1930 (Mar.-Apr.)—Moss Mites as Spore-bearers. Mycologia **22**:94-96, fig. 1.

31. SAME. 1931 (August)—A Common Arboreal Moss Mite *Humerobates humeralis*. Occ. Papers Boston Soc. Nat. Hist. **5**:369-382, pl. 19.

31a. SAME. 1933 (Sept.)—Two Winged Mossmites of the Nilgiri Hills. Records Indian Mus. **35**:371-374, pl. 9.

32. SAME. 1933 (Nov.)—The Primitive Galumninae (Oribatoidea-Acarina) of the Middle West. Am. Midl. Nat. **14**:680-703, pls. 13,14.

32a. SAME. 1933 (Dec.)—Aparity among the Oribatidae (Acarina). Canad. Ent. **65**:263-264.

33. SAME. 1934 (March)—The Galumnas (Oribatoidea-Acarina) of the Northeastern United States. Jour. N. Y. Ent. Soc. **42**:87-124, pls. 10-12.

34. SAME. 1935 (March)—The Species of Zetes (Oribatoidea-Acarina) of the Northeastern United States. Same **43**:51-94, pls. 7-10.

35. SAME. 1935 (July and Nov.)—The Large-winged Mites of Florida. Fla. Ent. **19**:1-14, pls. 1, 2; 17-31, pl. 3.

36. SAME. 1935 (Dec.)—On Some Large-winged Mites of the Southwestern States. Pomona College Jour. Ent. Zoöl., 5 pp., 11 figs.

37. OUDEMANS, A. C. 1919 (June)—Notizen über Acari, 26. Reihe (Oribatidea, Gruppe der Galumnae). Arch. f. Naturg. **83**(A, 4):1-84, 114 txt. figs.

38. PACKARD, ALPHEUS SPRING. 1888—The Cave Fauna of North America. Nat. Acad. Sci. **4**(pt.1):Memoir 1, 156 pp., 26 pls.

39. SELLNICK, MAX. 1926—Milben aus der Sammlung des Ungarischen National-Museum zu Budapest. Ann. Mus. Nat. Hungarici **22**:302-306, 7 txt. figs.

40. SAME. 1931—Acari: in Beier, Max, Zoologische Forschungsreise nach den Jonischen Inseln und dem Peloponnes, Teil XVI. Sitz. Akad. Wiss. Wien, Math.-naturw. Klasse, Abt. I, **140**:693-776, 60 txt. figs.

41. SAME. 1932—Oribatiden aus dem Karst. Zool. Jahrb., (Syst.) **63**:701-714, 11 txt. figs.

NORTHEASTERN FOREST EXP. STATION,
NEW HAVEN, CONN.

Diatoms from Lake Michigan—I.

B. V. Skvortzow

Under this title the author plans to publish several notes on the taxonomy of diatoms from Lake Michigan. Though work has been done on these plants in various other parts of North America, as far as I can discover the freshwater diatoms of this lake have been somewhat neglected.[1] For many years the only available atlas of American freshwater diatoms has been the Rev. Francis Wolle's *Diatomaceae of North America* (Bethlehem, Penna., 1890), a publication now out-of-date and difficult to interpret.

The seventeen species and varieties of diatoms recorded in the present paper were observed in a collection kindly sent to me by the Field Museum of Natural History at Chicago. The material was obtained by filtering Lake Michigan water from the city mains of Chicago in January, 1936. Species of two genera only, Stephanodiscus and Cyclotella, were found. The first was represented in the winter phytoplankton of the lake by four species: *S. niagarae,* reported from North America as a recent and fossil freshwater form, *S. carconensis* var. *pusilla,* known from Klamath Lake, Shasta County, California, as a recent and fossil freshwater form and recently found by me in Biwa Lake, central Nippon; *S. astraea* var. *minutula,* reported from North America, Europe, and Asia; and *S. Hantzschii,* a minute freshwater diatom. All species of Stephanodiscus occur in fresh or slightly brackish water, and all are pelagic and form part of the plankton of large lakes. The genus Cyclotella was represented in the collection by a total of 11 forms (8 species and 3 varieties). The three commonest species were *C. bodanica* with its two new varieties, var. *michiganensis* and var. *stellata; C. comta* and its var. *glabriuscula;* and a new species, *C. michiganiana.* The last species is an intermediate between *C. striata* and *C. caspia,* two forms reported from brackish water. Type material of new forms is in the author's personal collection. The illustrations were made by the author with the aid of a 2 mm. Leitz apochromatic objective and compensating ocular No. 4.

---

1 For earlier records see the following publications:

Ward, Henry B. 1896—A biological examination of Lake Michigan. Bull. Michigan Fish Comm. **6**: 101 pp., 5 pls. Cf. pp. 72-75, Diatomaceae identified by D. B. Ward.

Chase, H. H. 1904—Flora Michiganensis: Algae: Diatomaceae: a list of Michigan Diatomaceae. Ann. Rep. Michigan Acad. Sci. **5**:166-169. (No localities given).

Boyer, Charles S. 1927—Synopsis of North American Diatomaceae. Part I. Proc. Acad. Nat. Sci. Philadelphia **78**(1926): supplement, 228 pp.

Genus STEPHANODISCUS Ehrenb.

1. *Stephanodiscus niagarae* Ehrenb., Mikrogeologie, Taf. 35, fig. 21, 22 (1856); van Heurck, Synopsis, Taf. 95, fig. 13, 14 (1881); Grunow, Die Diatomeen von Franz Josefs-Land, 49 (1884); Schmidt, Atlas Diatomaceenkunde hrsg. v. Dr. Fr. Fricke, Taf. 227, fig. 1-9 (1901); Hustedt, Die Kieselalgen 2: 370 (1928).—Valve zone view in the central part convex with curved margins. Valve view circular with the surface separated into two areas. The inner area is composed of the extension of the radiating 84-107 rows of beads; each row in the marginal part is composed of 2-3 chains of beads which diminish slightly in size toward the central space; rows radial, alternately longer and shorter with distinct interspaces opposite the origin of the latter. Central area indistinct. The outer area consists of a submarginal beaded zone with large pointed spines and a distinct marginal striated rib. Valve diameter 0.045-0.070 mm. Rows 6-7 in 0.01 mm. Beads 10-15 in 0.01 mm. Plate I, Fig. 1, 22.—Common in the collection. Reported by Fricke as recent and fossil from freshwater at Niagara Falls and in Lake Erie and as fossil freshwater material from Mexico. This is the largest and stoutest species of Stephanodiscus. It differs from *S. astraea* in its larger size, longer spines, and the number of radiating rows of beads. According to Cleve, the large forms of *S. astraea* are similar to *S. niagarae* and are common in European waters, but Hustedt considers them different.

2. *Stephanodiscus niagarae* Ehrenb. var. *magnifica* Fricke in Schmidt, Atlas Diatomaceenkunde, Taf. 227, fig. 12, 13 (1901).—Differs from the type in its larger size and in its beaded rows of different shape: one row is filiform and double-beaded; the other diminishes in width toward the center and is 3-5-beaded in its lower part. The central space is undifferentiated except for one large isolated marking. Diameter of valve 0.072-0.080 mm. Marginal rib 0.002 mm. broad. Rows about 4 in 0.01 mm. Beads about 2 in 0.01 mm. To be illustrated as Plate II, Fig. 13 in the next paper of this series.—Abundant in the collection. Reported by Fricke as a fossil freshwater form from Mexico.

3. (?) *Stephanodiscus carconensis* Grun. var. *pusilla* Grun.: Schmidt, Atlas Diatomaceenkunde, Taf. 228, fig. 11, 12 (1901).—Valve in zone view convex at the middle, in valve view circular with 34 broad radiating rows, each diminishing slightly in width toward the central space. Rows at the margin 5-6-beaded. Valve diameter 0.028-0.0408 mm. Rows 3-3.5 in 0.01 mm. Beads 12-15 in 0.01 mm. Spines distinct, small. Plate I, Fig. 24-26.—Infrequent in the samples. It differs from the type in possessing a larger number of radiating rows. The type is known from Klamath Lake, Shasta County, California, as a recent and fossil freshwater form. Our small forms (see Plate I, fig. 24) are akin to *S. astraea* var. *intermedia* of Schmidt, ibid., Taf. 225, fig. 38, 39 (1901).

4. *Stephanodiscus astraea* (Ehrenb.) Grun. var. *intermedia* Fricke in Schmidt, Atlas Diatomoceenkunde, Taf. 225, fig. 38, 39 (1901); Hustedt,

Die Kieselalgen 2: 370 (1928).—Valve circular, flat up to within one-third the radial length from the margin, then strongly convex for half that distance. Marginal spines minute. Radiating rows broad, at the margin composed of 3-5 rows of small beads. Diameter of valves 0.028-0.030 mm. Rows 3.5 in 0.01 mm. Beads 12-15 in 0.01 mm. Plate I, Fig. 24.—Infrequent in the collection. A freshwater diatom reported from North America, Europe, and Asia. Ward 1896, 75.

5. *Stephanodiscus astraea* (Ehrenb.) Grun. var. *minutula* (Kütz.) Grun.: van Heurck, Synopsis, Taf. 95, fig. 7, 8 (1881); Schmidt, Atlas Diatomaceenkunde, Taf. 226, fig. 5, 12-17 (1901); Hustedt, Die Kieselalgen 2: 369. Fig. 193d, e (1928).—Valve circular, somewhat transversely undulate. Valve surface separated into two areas: the outer or marginal area forming a narrow smooth band with fine spines irregularly placed, the inner area composed of about 22-53 radiating rows of minutely spaced beads. The rows at the outer part of the valve have a double chain of beads. Rows radial, alternately longer and shorter, with distinct subulate interspaces opposite the origin of the latter. Central space indistinct. Beads or markings rounded, granular, diminishing in size toward the central space. Diameter of valve 0.009-0.0255 mm. Rows of beads 5-12 in 0.01 mm. Beads 12-15 in 0.01 mm. Marginal spines minute. Plate I, Fig. 5, 15, 19, 23.—Differs from the type in its smaller valves. Described by Ehrenberg in Mikrogeologie, Taf. 33, fig. 2, 3 (1856), from Oregon as *Discoplea oregonica* Ehrenb. Chase 1904, 168; Boyer, 1927, 61.

6. *Stephanodiscus Hantzschii* Grun., Beiträge zur Kenntniss der arctischen Diatomeen, 115. Taf. 7, fig. 131 (1880); van Heurck, Synopsis, Taf. 95, fig. 10, 11 (1881); Schmidt, Atlas Diatomaceenkunde, Taf. 225, fig. 23-29 (1901); Hustedt, Die Kieselalgen 2: 370. Fig. 194 (1928). *S. Hantzschii* var *pusilla* Grun., idem. fig. 132 (1880).—Valve minute, circular, from zone view plane or almost plane, or slightly convex in the central part. Surface composed of the extension of 18-25 radiating rows of small beads. Beads double or single, sometimes indistinct. Marginal rim indistinct (one form was seen—see Plate I, Fig. 17—with a distinct outer marginal area about 0.001 mm. broad). Diameter of valve 0.005-0.0136 mm. Rows 15-18 in 0.01 mm. Plate I, Fig. 9, 17.—Infrequent in the collection. Reported from fresh and brackish water.

Genus Cyclotella Kütz.

7. *Cyclotella comta* (Ehrenb.) Kütz.: Schmidt, Atlas Diatomaceenkunde, Taf. 224, fig. 1-4 (1900); van Heurck, Synopsis, Taf. 92, fig. 25, 26, Taf. 93, fig. 1-9, 11-13, 20 (1881); Hustedt, Die Kieselalgen 2: 354. Fig. 183a-d (1928).—Frustule plane or slightly undulate. Valve surface separated into two areas, the inner area covered with distinct beads irregularly placed or in radiating rows, the outer area containing a marginal striated rib and radiating striae with distinct dark markings on the lower part. Valve diameter 0.01-0.017 mm. Marginal striae 14-15 in 0.01 mm. Plate I, Fig. 4, 12, 13.—Very

common in the collection. Reported from Europe, Asia, and America. Ward 1896, 75; Chase 1904, 166; Boyer 1927, 40.

8. *Cyclotella comta* (Ehrenb.) Kütz. var. *glabriuscula* Grun.: Schmidt, Atlas Diatomaceenkunde, Taf. 224, fig. 26-28 (1900).—Differs from the type in having the central area covered with densely radiating beaded rows, forming in the center an isolated group of beads. Diameter of the valves 0.017-0.019 mm. Striae 15 in 0.01 mm. Plate I, Fig. 6.—Common in the collection. Known from plankton of European lakes.

9. *Cyclotella ocellata* Pantocsek, Bacillarien des Balatonsees, 104. Taf. 15, fig. 318 (1912); Schmidt, Atlas Diatomaceenkunde, Taf. 224, fig. 38, Taf. 266, fig. 8-12 (1900); Hustedt, Die Kieselalgen 2: 340. Fig. 173 (1928).—Valve minute with distinct marginal rib half as wide as the diameter of the valve. The rib is covered with fine radiating striae. Central area with 3-4 large markings or beads and sometimes with several small puncta. Diameter of valve 0.0078-0.0080 mm. Striae 15 in 0.01 mm. Plate I, Fig. 8, 11, 27.—Common in the collection. A freshwater diatom.

10. *Cyclotella stelligera* Cleve & Grun.: van Heurck, Synopsis, Taf. 94, fig. 22-27 (1881); Schmidt, Atlas Diatomaceenkunde, Taf. 222, fig. 48, 49 (1900).—Frustule strongly convex, minute. Valve surface with marginal striae 1/3-1/2 as long as the diameter of the valve. Central area broad with several beads forming a star in the center. Diameter of valve 0.0068-0.0136 mm. Striae 15-18 in 0.01 mm. Plate I, Fig. 14, 29.—Infrequent in the collection. Common in fresh water.

11. *Cyclotella Kuetzingiana* Thwaites: van Heurck, Synopsis, Taf. 94, fig. 1, 4-9 (1881); Schmidt, Atlas Diatomaceenkunde, Taf. 222, fig. 1-7, 13, 14 (1900); Hustedt, Die Kieselalgen 2: 338 (1928).—Valve minute, circular with fine radiating striae with a length of about one-half the diameter of the valve. Central area punctate and sometimes containing two isolated beads. Diameter of valve 0.0085 mm. Striae 15 in 0.01 mm. Plate I, Fig. 2, 16.—The form seen here is smaller than the type. Reported from fresh water.

12. *Cyclotella Meneghiniana* Kütz.: van Heurck, Synopsis, Taf. 94, fig. 11-14, 17-20 (1881); Schmidt, Diatomaceenkunde, Taf. 222, fig. 25-31 (1900); Hustedt, Die Kiesalalgen 2: 341 (1928).—Valve surface with inner smooth area in diameter one-half that of the valve, and with outer area containing robust radiating striae. Diameter of valve 0.010-0.012 mm. Striae 9 in 0.01 mm. Plate I, Fig. 20.—Rare in this collection. Common in fresh water. Chase 1904, 166.

13. *Cyclotella operculata* (Ag.) Kütz.: van Heurck, Synopsis, Taf. 93, fig. 22-24 (1881); Schmidt, Atlas Diatomaceenkunde, Taf. 222, fig. 42-47 (1900); Hustedt, Die Kieselalgen 2: 351. Fig. 181a, c, d (1928).—Valve separated into two areas; the outer (with a width of almost one-third the diameter of the valve) marked with radiating rows in the middle part of which are distinct puncta; and the inner area broad-circular, irregularly punc-

tate in the center and smooth toward the margin. Diameter of valve 0.010-0.024 mm. Striae 10-15 in 0.01 mm. Plate I, Fig. 21, 28, 32.—Infrequent in this material. Reported from fresh water. Chase 1904, 166.

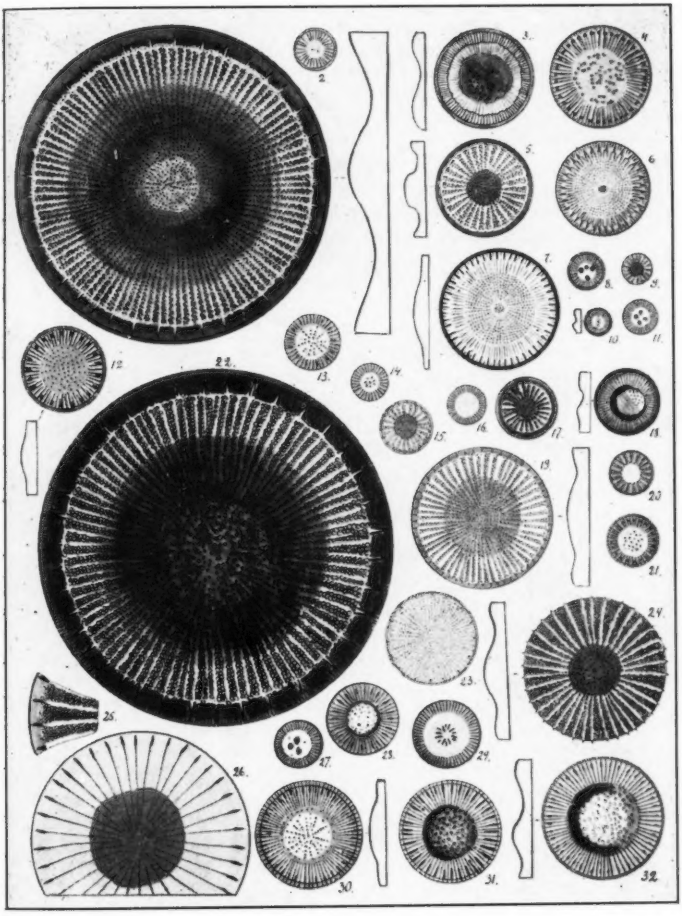
14. *Cyclotella bodanica* Eulenstein: van Heurck, Synopsis, Taf. 93, fig. 10 (1881); Schmidt, Atlas Diatomaceenkunde, Taf. 224, fig. 29-32 (1900); Hustedt, Die Kieselalgen 2: 356 (1928).—Valve circular, the outer area flat and one-third the length of the radius of the valve in width, the inner area convex. The outer area is marked with a distinct marginal striated rib and is divided into two radiately striated zones: an outer (marginal) zone with robust striae, 5-6 in 0.01 mm., and an inner densely striated zone with 12-15

PLATE I

FIGURES

1. *Stephanodiscus niagarae* Ehrenb.
2. *Cyclotella Kuetzingiana* Thwaites.
3. *Cyclotella michiganiana*, sp. nov.
4. *Cyclotella comta* (Ehrenb.) Kütz.
5. *Stephanodiscus astraea* (Ehrenb.) Grun. var. *minutula* (Kütz.) Grun.
6. *Cyclotella comta* (Ehrenb.) Kütz. var. *glabriuscula* Grun.
7. *Cyclotella bodanica* Eulenstein.
8. *Cyclotella ocellata* Pantocsek.
9. *Stephanodiscus Hantzschii* Grun.
10. *Cyclotella michiganiana*, sp. nov.
11. *Cyclotella ocellata* Pantocsek.
12. 13. *Cyclotella comta* (Ehrenb.) Kütz.
14. *Cyclotella stelligera* Cleve & Grun.
15. *Stephanodiscus astraea* (Ehrenb.) Grun. var. *minutula* (Kütz.) Grun.
16. *Cyclotella Kuetzingiana* Thwaites.
17. *Stephanodiscus Hantzschii* Grun.
18. *Cyclotella michiganiana*, sp. nov.
19. *Stephanodiscus astraea* (Ehrenb.) Grun. var. *minutula* (Kütz.) Grun.
20. *Cyclotella Meneghiniana* Kütz.
21. *Cyclotella operculata* (Ag.) Kütz.
22. *Stephanodiscus niagarae* Ehrenb.
23. *Stephanodiscus astraea* (Ehrenb.) Grun. var. *minutula* (Kütz.) Grun.
24, 25. *Stephanodiscus carconensis* Grun. var. *pusilla* Grun.?
26. *Stephanodiscus carconensis* Grun. var. *pusilla* Grun.?
27. *Cyclotella ocellata* Pantocsek.
28. *Cyclotella operculata* (Ag.) Kütz.
29. *Cyclotella stelligera* Cleve & Grun.
30. *Cyclotella bodanica* Eulenstein var. *stellata*, var. nov.
31. *Cyclotella bodanica* Eulenstein var. *michiganensis*, var. nov.
32. *Cyclotella operculata* (Ag.) Kütz.

PLATE 1



striae in 0.01 mm. In the latter zone of striae, two striae from opposite sides of the valve are shortened and terminate in distinct beads. The inner (central) area is densely beaded in closely set rows (12-15 rows in 0.01 mm.), except in the central space where a compact group of beads is segregated. Valve diameter 0.020-0.024 mm. Plate I, Fig. 7.—Common in the collection. A freshwater species, reported from Europe and America.

15. **Cyclotella bodanica** Eulenstein var. **stellata** var. nov. Differt a typo punctis in area centrali stellatim dispositis atque punctis orbiculatis ad marginem areae centralis in unica serie dispositis; valvis diametro 0.0238 ad 0.0250 millimetrum metientibus; striis marginalibus radiantibus, circiter 15 in 0.01 millimetro; aculeatis 9 in 0.01 millimetro.—Hab., in aquis lacus Michigan prope Chicago.—Plate I, Fig. 30. This variety differs from the type in having its central area covered with rows of beads arranged in the form of a star; a single row of puncta is disposed about the margin of the central area. Diameter of valve 0.0238-0.0250 mm. Striae 15 in 0.01 mm.—Common in the collection.

16. **Cyclotella bodanica** Eulenstein var. **michiganensis** var. nov. Differt a typo area centrali punctata et irregulariter granulata; valvis diametro 0.0180 ad 0.204 millimetrum metientibus; striis marginalibus radiantibus, 12 in 0.01 millimetro; aculeatis 8 in 0.01 millimetro.—Hab., in aquis lacus Michigan prope Chicago.—Plate I, Fig. 31. This variety differs from the type in having its central area punctate and densely covered with distinct granular subequal beads. Two distinct isolated puncta occur among the marginal radiating striae. Diameter of valve 0.018-0.204 mm. Marginal striae 12 in 0.01 mm.—Common in the collection.

17. **Cyclotella michiganiana** sp. nov. Valvis diametro 0.0050 ad 0.0204 millimetrum metientibus; striis marginalibus distinctis, in duabus zonis radiantibus, circiter 15 ad 18 in 0.01 millimetro; aculeolis nullis; area centrali hyalina, irregulariter punctata, punctis nonnullis uno loco validioribus.—Hab., in aquis lacus Michigan prope Chicago—Plate I, Fig. 3, 10, 18. Frustule in the middle depressed and undulate. Valve circular, separated into two areas: the central area with a diameter of one-half that of the valve, at one side covered with large beads irregularly disposed, and the marginal area composed of one or two zones of radiating striae and a robust marginal rim. Valve diameter 0.0050-0.0204 mm. Striae 15-18 in 0.01 mm.—Common in the collection. This species differs from *C. striata* and its varieties in its coarser striae and in the minute size of the valve. It differs from *C. caspia* in the nature of its central area. Both of these related species are reported from brackish waters.

HARBIN, MANCHUKUO.

An Occurrence of Sphaerotheca lanestris in Mexico

G. M. Watkins and C. H. Muller

In August, 1934, a number of individuals of *Quercus polymorpha* Cham. & Schl. with severely diseased foliage were observed along the steep sides of Guajuco Canyon, near the village of El Cercado (Municipality of Villa de Santiago), Nuevo Leon, Mexico. Similarly affected trees of the same species of oak were seen in nearby canyons at this altitude, approximately three thousand feet. The lower surfaces of the leaves were covered heavily with a thick woolly mycelial growth (see Fig. 1), the color ranging from creamy buff to dark brown. Microscopic examination showed that this fungus checked closely with the original description of *Sphaerotheca lanestris* Harkness (1884), as well as with the subsequent account by Salmon (1900).

The original description of *S. lanestris* by Harkness was based on material collected from *Quercus agrifolia* at San Francisco, California. Tracy and Galloway (1888) subsequently reported the fungus on the same oak at Napa City, California, and Tracy and Earle (1895) recorded it as occurring on *Q. alba, Q. minor, Q. prinus,* and *Q. rubra* in Mississippi, Alabama, Illinois, and Iowa. Seymour (1929) lists it as well on *Q. falcata, Q. macrocarpa,* and *Q. stellata.* The observation of *S. lanestris* in Nuevo Leon increases its known host range to include *Q. polymorpha,* and extends knowledge of its geographic distribution to the Sierra Madre Oriental in that state.

Toro (1934) has reëmphasized the fact that "the 'powdery mildews' do not occur in the perfect or perithecial stage in the tropics," and that the determination of material from such regions must be based on the conidial stage alone. But Mexico, instead of having a climate of extreme uniformity, as some botanists seem to believe, and being perhaps a vast tropical desert in the north and tropical forest in the south, actually has in large part a terrain of such topographic diversity as to induce almost all conceivable variations in climate (Page, 1930). In the state of Nuevo Leon the eastern Sierra Madre includes several peaks which are snow-covered a large part of the year, in spite of their location between one and two degrees north of the tropic of cancer. Our collection of the perithecial stage of *S. lanestris* in the Sierra Madre Oriental in no way refutes Toro's statement, since the localities in which this fungus has been collected are all in an altudinal zone reported by residents to have a temperate climate, with frosts occurring from one to several times a year. To judge from the luxuriant development of pine, oak, and hickory forests, the rainfall is moderate. Where the host species occurs in the warm, dry areas below, or in the much cooler altitudes above, *S. lanestris* was not evident.

Specimens of this collection (Watkins and Muller no. 1) are deposited in the herbarium of the University of Illinois.

REFERENCES

HARKNESS, H. W. 1884—New species of Californian fungi. Calif. Acad. Sci. Bull. **1**:29-47.

PAGE, J. L. 1930—Climate of Mexico. U. S. Monthly Weather Rev., Suppl. **33**:1-30.

SALMON, E. S. 1900—A monograph of the Erysiphaceae. Mem. Torr. Bot. Club **9**:1-292.

SEYMOUR, A. B. 1929—Host index of the fungi of North America. Cambridge, Mass.

TORO, R. A. 1934—Perisporiales. Chapter IX *in* CHARDON, C. E., and R. A. TORO. Mycological explorations in Venezuela. Monogr. Univ. Puerto Rico, Ser. B., no. 2.

TRACY, S. M., *and* F. S. EARLE. 1895—Mississippi fungi. Miss. Agr. Exp. Sta. Bull. **34**.

TRACY, S. M. AND B. T. GALLOWAY. 1888—Notes on western Erysipheae and Peronosporeae. Jour. Mycol. **4**:33-36.

COLLEGE STATION, TEXAS
AND
DEPT. OF BOTANY,
UNIVERSITY OF ILLINOIS,
URBANA, ILLINOIS.

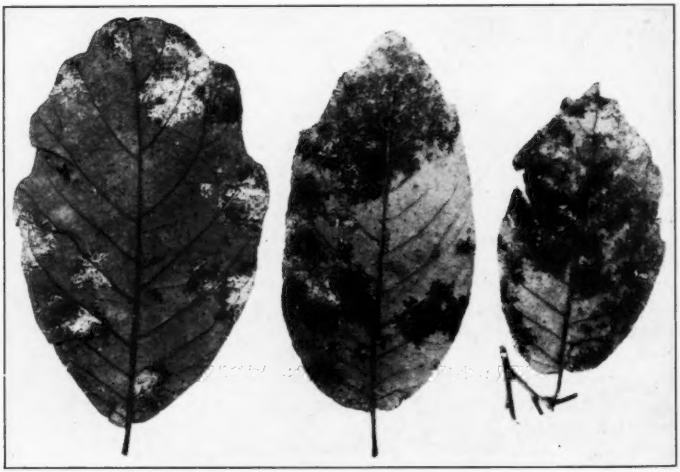


Fig. 1. Leaves of *Quercus polymorpha* typically infected by *Sphaerotheca lanestris*. x ½. Photograph by Mr. Howard Berry.

Phytosociological Studies in the Pinelands of Southeastern Louisiana

William T. Penfound and Allan G. Watkins

The Florida Parishes of Southeastern Louisiana include hardwood uplands, mixed shortleaf and hardwood uplands, longleaf pine hills and longelaf pine flats. The longleaf pine flats, which are the subject of this investigation, are at the southwestern edge of the longleaf-slash pine forest which extends along the seaboard as far north as North Carolina. This forest is very important economically since it not only produces the finest southern pine lumber but also most of the naval stores produced in the United States. It is also the most important of our southern range due to its well-developed herbaceous cover of grasses, legumes and other palatable plants.

In flat pinelands the soils are characterized by high acidity and poor drainage. They are usually gray or light gray in color with gray mottled or yellow impermeable and poorly drained subsoils. They belong either to the Caddo, Beauregard, Norfolk, or Myatt series. Extensive shallow swamps, and numerous 'sloughs' and ponds give evidence of a high water table. The better drained lands usually support a forest of longleaf pine, either in pure stands or mixed with loblolly or slash pines, but the shallow swamps are characterized by slash pine and pond cypress in varying degrees of mixture (Pessin, 1933).

Included in the longleaf pine flats are all four of the principal timber pine species of the Gulf Coastal States. In order of increasing northward range they are as follows: slash pine *(Pinus caribaea* Morel.), longleaf pine *(P. palustris* Mill.), loblolly pine *(P. taeda* L.), and shortleaf pine *(P. echinata* Mill.). Although all four of these species do occur in the longleaf pine flats, the loblolly pine appears to be abundant only in secondary successions and the shortleaf pine is an infrequent species.

Longleaf pine originally ranged from the extreme southeastern corner of Virginia southward to Florida and westward to Texas, but at the present time its range has been somewhat diminished. The longleaf pine forest is usually characterized by pure stands of longleaf with few or no small trees or shrubs. It was aptly described by Hilgard, as far back as 1860, when he wrote, "The pine forest is almost destitute of shrubby undergrowth, and during the growing season appears like a park, whose long grass is often very beautifully interspersed with brilliantly tinted flowers." These longleaf pine flatwoods correspond to Forest Cover Type No. 63 of the report of the Committee on Forest Types (Hawley, R. C., et al, 1932). Along the coast, and particularly bordering ponds, longleaf mingles with loblolly and slash pines (Forest Cover Type

No. 73). In 1930 it was estimated by Forbes that there were about 8,600,000 acres of virgin longleaf pine timber throughout the south and that it was being cut at the rate of 750,000 acres per year. At this rate all the old-growth (virgin) longleaf pine will have been cut in the course of the next few years. The rapid cutting of the longleaf forests is very unfortunate since a considerable acreage of longleaf pineland remains barren unless protective measures are undertaken.

In relation to slash pine Forbes (1930) states that "extensive pure stands of virgin slash pine were rare except in the lower peninsula and Gulf Coast of Florida." In Eastern Louisiana old-growth slash pine timber is found along small streams and in swamps throughout the flatwoods of the Coastal plain. Pure stands of slash pine (Forest Cover Type No. 74) are listed as occurring in Louisiana but pond cypress, *Taxodium ascendens* Brongn., usually is found associated with it. Since the loblolly pine-slash pine forest (Forest Cover Type No. 72) occurs only as second-growth timber no investigations have been made thereon. In addition to the old-growth slash pine timber there are extensive areas of beautiful second-growth on adjacent cut-over longleaf land. With the increase of fire protection, slash pine undoubtedly will be greatly benefitted in its competition with longleaf on the moist flatlands and slopes and may become much more important economically than it is at present.

The area under investigation is known as the Knott tract of the Great Southern Lumber Company. It is located some three miles east of Mandeville and extends interruptedly over an area of about 15 square miles. The Knott tract was the subject of considerable discussion in 1934-1935 as a possible State Forest, but little was done to effect its establishment. Cutting began in the summer of 1935 and undoubtedly will be completed by January, 1938. This area included excellent stands of old-growth longleaf pine over 200 years old, and of slash pine-pond cypress 165 years old. It also included merchantable second-growth stands of mixed longleaf and loblolly pines 85 years of age and dense, second-growth of pure longleaf pine, also 85 years of age but hardly of merchantable size. In addition there were hundreds of acres of cut-over longleaf pine in which there was little or no reproduction. The area was completely protected against fire during 1933 and 1934, but was subjected to annual burning until that time.

Procedure

Three separate associations, and a second-growth longleaf stand of one of the associations were investigated critically. Two stands of virgin longleaf pine were studied in the autumn of 1935 and another was analyzed in the spring of 1936. The second-growth longleaf was studied only once — in the autumn of 1935. Two excellent stands of the slash pine-pond cypress community were studied, one in the autumn of 1935 and the other in the spring of 1936. The same was true for the cut-over longleaf pine community (pine barrens, savanna).

After a general reconnaissance of an association and establishment of stations the following procedure was approximately adhered to. General notes were taken regarding location and description of area and character and composition of each association. Photographs were taken of each station to show the general aspect of the community. Each stratum in each association was then described, including notes on dominant and associated plants, estimated cover, estimated height and crown cover of trees and depth of needle litter and other debris on the ground.

Ten plots of one-tenth acre each (66 feet square) were laid out either in a continuous row or in two nearly equal parallel rows. On these plots counts were made of the total number of trees of each species, and stumps by species (if identifiable). Measurements were made of tree diameter (at breast height) in at least half of the plots with a Forest Service diameter tape. Heights of trees, taken at random, were determined by means of a hand level using a base line of 100 feet. Annual ring counts were made on all available freshly cut stumps. Since longleaf pine seedlings remain in the 'grass' stage for three or more years it is necessary to add about 9 years to the actual ring count. Soil samples were taken on the actual plots at depths of 0″-6″ and 24″-30″ in triplicate for later determination of water content (based on dry weight), organic matter and hydrogen ion concentration.

In making a phytosociological analysis of the associations, twenty-five temporary meter quadrats were established at intervals of five meters and data on frequency, covergrade, and phenology were recorded for each species. The data were kept on coordinate paper, the list of species being placed on the ordinate axis and the number of the quadrats along the alternate axis. As each species was located on a quadrat it was allotted an estimated covergrade according to the following symbols: v = less than 1%, 1 = 1%-5%, 2 = 6%-25%, 3 = 26%-50%, 4 = 51%-75%, and 5 = 76%-100% of the quadrat area. Recording was started in the lower left hand corner of the sheet working upward along the species axis and toward the right along the quadrat axis. As soon as the listing of the quadrat was completed a survey was made of each community to locate species not found in the quadrats. These were recorded in an "extra species" list.

Specimens of all herbaceous species were collected, removed to the laboratory for definite identification and entered in the Tulane University herbarium. In the matter of nomenclature Small's (1933) "Manual of Southeastern Flora" has been strictly followed. Upon identification of all species the frequency and percentage frequency of each species was calculated. The average covergrade per quadrat for each species was also computed (v being given a rating of 0.20) by totaling the assigned figures in each quadrat and dividing by the number (25) of quadrats. The total coverage of all species in the quadrats was then determined by adding the average cover of each species. From this figure it was then possible to obtain the covergrade of the average species.

Virgin Longleaf Pine Association

The longleaf pine association is characterized by a very open stand of tall, slender trees, the absence of an understory, either of other tree species or shrubs, and the presence of a well-developed 'grassland' forest floor. An excellent stand of old-growth longleaf pine forest was located 1.8 miles north of U. S. highway 61 on the CCC road. This was studied according to the procedure just described and was logged shortly after the investigation was completed (Fig. 1).

This forest presented the usual open stand with an estimated crown cover of 30%. It consisted chiefly of longleaf pine *(Pinus palustris)* with a few

Fig. 1. Virgin longleaf pine forest being timbered, autumn, 1935.

TABLE 1.

Data on trees in the virgin longleaf pine association.

Measurement or count	Average or no. per acre	Variation per plot
Total longleaf trees	82	5-12
Total longleaf stumps (mostly slivered)	32	1-9
Original trees per acre	114	6-19
Height of trees in feet (10 trees)	107.1	99-115
Diameter (4.5 feet) in inches (10 trees)	21.4	15-27
Diameter (1 foot) in inches (10 trees)	24.9	18-31
*Annual ring count (10 trees)	210.0	190-215
Basal area (sq. ft. per acre)	205.0	——

* Although the average ring thickness was about 1.5 mm. the inner rings were much broader. In fact the first 60 years of growth almost exactly equalled the last 150 years of growth in diameter.

seedlings of red gum *(Liquidambar styraciflua)* up to five feet high and occasional seedlings of *Quercus stellata* and *Diospyros virginiana.* The longleaf trees had an average d.b.h. of 21.4 inches, an average height of 107.1 feet, and gave a basal area of 205 square feet (Table 1). There was no definite shrub stratum in this stand but there were occasional specimens of *Ilex glabra, Callicarpa americana, Crataegus spathulata,* and *Smilax Bona-Nox.* A rather well developed ground cover estimated at about 90% was present, with *Andropogon virginicus* and *Andropogon scoparius* making up about 30% of the total (Table 4). Other important grasses were *Aristida virgata, Axonopus compressus* and *Panicum rhizomatum.* Moss occasionally formed a ground layer and pine litter covered the area to a depth of ¼ inch to 1 inch, sufficient in the denser part of the stand to prevent the growth of herbaceous vegetation.

A second stand of longleaf pine about one mile from the above was sampled in the same manner. Neither the number, height, diameter or age of the trees differed significantly from the above stand. It did vary in having no loblolly trees whatsoever, less pine 'straw' and therefore a somewhat denser, herbaceous cover. Seven of the eight important herbaceous species were common to both stands and these species contributed 70% or more of the total cover in each stand sampled. These species were *Andropogon virginicus, A. scoparius, Aristida virgata, Axonopus compressus, Elephantopus nudatus, Panicum angustifolium, P. longiligulatum* and *P. rhizomatum.*

The stand of virgin longleaf pine studied in the spring of 1936 was about one-half mile north of U. S. highway 61, adjacent to the logging spur of the Gulf, Mobile, and Northern Railroad. The stand consisted of pure longleaf pine estimated at 100 feet in height and an open crown cover of 20%. It differed from the other two longleaf stands in having a few longleaf trees of pole size and a considerable number of loblolly seedlings. There was no definite shrub stratum but occasionally specimens of *Rhus Copallinum, Vaccinium tenellum, Arsenococcus ligustrinus, Quercus stellata,* and *Quercus marylandica* were noted.

The herb cover was similar to that in the other longleaf stands with *Andropogon virginicus* and *Aristida virgata* as the most important species (Table 5). But the stand included many species not discovered in the autumn such as *Panicum chamaelonche, P. chrysopsidifolium,* and *P. Thurowii* (Table 4). Many species also were found in the autumn survey such as *Eragrostis refracta, E. hirsuta, E. Elliotti, Panicum verrucosum* and *P. longifolium* which were not identified in the spring.

The authors have examined two other stands of virgin longleaf pine. One of these was located at Kisatchie, La. and the other at Savannah School, Miss. Although located in widely separated areas having diverse topography and soil, all five stands of the longleaf pine association were very similar. They were all characterized by a park-like open stand of longleaf pine trees with a crown cover of about 30%, an average height of 110 feet, and an average

d.b.h. of about 20 inches even though the average age varied from 150 to 250 years. The stands were all noted for the absence of a shrub stratum and the presence of a well-developed herbaceous layer forming a nearly continuous cover. This 'grassland' ground cover makes this forest the finest of our southern ranges (Wahlenberg and Gemmer, 1936).

The herbaceous stratum usually contributed a cover of approximately 100%, using a clipped lawn as a basis. In all five communities the important species were the same. These included *Aristida virgata, Andropogon scoparius, A. virginicus, Elephantopus nudatus,* and *Panicum rhizomatum.* Of these, *Andropogon virginicus* was the most abundant and contributed the greatest amount of cover. Perhaps other species should be included in the above list but most of these are either much less abundant or else exert their influence over a shorter period. One of these is an introduced species *(Axonopus compressus),* valuable as a forage grass.

Second-growth Longleaf Pine

The second-growth stand of longleaf pine studied is adjacent to U. S. Highway 61, one-quarter of a mile southwest of the lumber camp, and was still uncut in June, 1936. This strip of timber, only 200 yards wide and a half mile long, presents a remarkably even-aged, dense, young stand of longleaf trees (Fig. 2). They averaged 93 years of age, 12 inches d.b.h., 95 feet in height, and 164 trees per acre (Table 2.) This isolation of a young even-aged pure stand of longleaf pine might be explained as resulting either from a hurricane or from a clear cut about 1845. Just across the road to the south it gives way to a loblolly-longleaf community with trees of similar age and size. To the north it merges rather abruptly on virgin longleaf timber about 200 years old, nearly 2 feet in diameter but with only about 65 trees per acre.

This second-growth longleaf pine community consists of a close stand of slender 'pole' and 'saw-log' trees with an estimated cover grade of 50%. Longleaf composes more than 95% of the stand, loblolly making up the remainder. The longleaf trees averaged about 12 inches in diameter whereas

TABLE 2

Data on trees in second-growth longleaf pine association.

Measurement or count	Average or no. per acre	Variation per plot
Total longleaf trees	164	14-19
Total loblolly trees	3	0-2
Total stumps	83	2-11
Original trees per acre	250	16-29
Height (Av., 10 trees, in feet)		
Longleaf	96.0	90.6-104.6
Loblolly	94.7	82.6-102.6
Diam. b.h. (Ave., 100 trees, inches)		
Longleaf	12.1	3.2-18.7
Loblolly	22.7	20.5-26.0
Annual rings (Ave. 10 trees)		
Longleaf	93	89-104

the loblolly averaged about 23 inches in diameter (Table 2). No longleaf and only a few loblolly seedlings were evident. Although some scattered shrubs such as *Azalea, Cyanococcus, Ilex, Lasiococcus, Rhus* and *Symplocos,* as well as seedlings and saplings of *Quercus* and *Liquidambar* were present, there was no definite shrub stratum. Due to the heavy crown cover and

Fig. 2. Second-growth longleaf pine forest, autumn, 1935.

abundant pine 'straw' the ground cover was very meager. Of the total ground cover (about 35%), four grasses, *Andropogon virginicus, A. scoparius, Aristida virgata,* and *Panicum sp.* were the only contributors of importance (Table 4). *Panicum ciliatum* and *P. longifolium* were next in abundance.

Cut-over Longleaf Pineland Community

This example of a cut-over longleaf forest area was located approximately 1 mile north of U. S. 61 on west side of Knott tract (Fig. 3). The station was established 100 yards east of an area of virgin longleaf in which

cutting was just beginning. The virgin longleaf adjacent to the cut-over area was a part of an extensive tract of which most had already been cut. The trees were about 24 inches d.b.h., approximately 100 feet in height and 195 years old as indicated by ring counts on random specimens. This agrees closely with the longleaf plots studied.

The cut-over area included an occasional deformed tree and practically no reproduction but was characterized by a great number of broken and fire-scarred snags and stumps (Fig. 3). The number of snags and stumps on the acre studied was 75, although depressions indicated the existence of others in the past. In the ten plots studied (66 feet square) the number of snags and stumps per plot varied from 3 to 11, indicating a fairly even distribution of the original forest trees. The area had apparently been cut about 30 years previously as indicated by the average age (165 years) of stumps selected at random. The average diameter of the stumps without bark was 21.7 inches which was approximately that of the longleaf areas studied.

A rather sparse shrub stratum of scattered specimens of *Ilex* and *Cerothamnus*, obtained over the area. Seedlings of *Diospyros virginiana, Nyssa sylvatica, Quercus stellata, Q. marylandica* and *Q. virginiana* as well as very small seedlings of longleaf and loblolly pines were present but not numerous. The cut-over area was definitely wetter than the forest as indicated by the presence of more hydric species, especially of Sphagnum, and by a greater number of herbaceous species in the ground cover. The total cover was over 200% using a closely clipped lawn as 100% coverage (Table 5). This was due to the presence of three distinct layers; a tall grass layer consisting mainly of *Andropogon virginicus, A. Elliottii,* and *Aristida virgata,* a short grass layer of *Panicum angustifolium, Axonopus compressus* and *Rynchospora spp.,* and a ground layer of *Sphagnum, Drosera* and rosettes of transgressive species (Table 4). In addition *Aster dumosus, Endorima uniflora,* and *Eupatorium semiserratum* were conspicuous during the autumn aspect.

The example of the cut-over longleaf pine area studied in the spring was approximately 1 mile north of U. S. 61 on the west side of the Knott Tract. The community is adjacent to and includes the unburned part of the plot studied in the autumn, most of which was burned during the winter. No burning had occurred on this plot for over three years. There were four seed trees on the plot and a number of fire-scarred snags and stumps. The moist condition of the community was attested by the numerous crayfish mounds.

The only woody plants found on the plot were four seed trees of longleaf pine and a few seedlings of loblolly and longleaf pines. The herbaceous cover was similar to that of the community studied in the autumn but less dense and with fewer species (Tables 4, 5). Species not blooming until late summer were not discovered in the spring survey. These included *Aristida virgata, Andropogon tener, Eragrostis refracta, E. Elliottii, Gymnopogon brevifolius, Panicum longifolium* and *Paspalum ciliatifolium.* In addition there

were several plants of the spring flora not listed in the autumn survey. Among these were *Panicum albomarginatum, P. chrysopsidifolium, Pilostaxis ramosa, P. cymosa, Lobelia floridana,* and *Hypericum gymnanthum.*

Fig. 3. Cut-over longleaf lands with scattered seed trees, autumn, 1935.

TABLE 3

Data on trees in slash pine-pond cypress community.

Measurement or count	Average or no. per acre	Variation per plot
Slash pine trees	105	5-14
Slash pine stumps	32	0-7
Pond cypress trees	45	0-13
Pond cypress stumps	20	0-6
Total trees and stumps	202	9-37
Height in ft. (Ave. 10 trees)		
Slash pine	102.1	95.9-121.9
Pond cypress	74.7	58.5-102.5
Diam., inches (Ave. 50 trees)		
Slash pine	13.8	5.5-22.4
Pond cypress	7.1	3.2-20.8
Annual rings (Ave. 10 trees)		
Slash pine	135	120-160
Pond cypress	108	103-112
Basal area (sq. ft. per acre)		
Slash pine	103.9	
Pond cypress	11.4	

Slash Pine-pond Cypress Community

The slash pine-pond cypress community develops in poorly drained areas where standing water is present for two or more months during the winter and early spring. It is characterized by very slender trees of slash pine and pond cypress in varying degrees of mixture, the absence of a shrub stratum and a heavy herbaceous cover. The example studied in the autumn was situated on Louisiana highway No. 464, about 6 miles northeast of Mandeville, La. (Fig. 4). This particular swamp was considered by old time lumbermen to be the most extensive they had ever seen. It included over two sections, (some 1500 acres) of virgin timber. Standing water (from 2 to 10 inches deep) is usually present from January to April and sometimes as late as June, although it is quite dry from August to November.

The stand, of approximately 150 trees per acre, consisted of 65% slash pine and 35% pond cypress, with an estimated crown cover of 30% to 35%. The pines averaged 135 years of age, 102 feet in height and 13.8 inches d.b.h. (Table 3). Slash pine reproduction, mostly under 1 inch d.b.h., occurred in patches. There was typically no shrub cover, though *Cerothamnus carolinensis, Ilex glabra,* and *Tamala pubescens* did occur. The latter, though normally a tree, was found fruiting here at a height of 2½ feet. A dense herbaceous cover, separable into three layers, literally covered the ground (Table 5), The upper layer of tall grasses (mostly *Panicum virgatum)* was sparse, but the middle layer, consisting mainly of various species of *Panicum* and *Rynchospora* formed an almost unbroken canopy (Table 4). In addition the ground stratum of *Sphagnum, Drosera* and the rosettes of several composites, presented a continuous cover over much of the area. Moreover, the pine litter, usually about one inch in thickness, was often intermingled with swamp debris (wash) to form a dense ground cover under which the soil surface remained almost continuously moist. A notable character of this community is the complete absence of legumes.

A second example of the slash pine-pond cypress community was located some 2 miles north of Louisiana highway No. 464, and about 8 miles northeast of Mandeville, La. The stand was very similar to that studied in the autumn but with a greater proportion of slash pine as compared with the pond cypress, more 'rough', less ground cover, and less peat moss. It was also somewhat more open and the trees somewhat larger. Crown cover was estimated at 25%-35% and the average d.b.h. of the slash pine was 16 inches. Slash pine made up 80% of the stand, the rest being contributed by the pond cypress which produced numerous knees up to 8 inches high. Seedlings of slash pine were abundant and there were occasional specimens of *Nyssa biflora, Rhus Copallinum, Rubus* sp., *Tamala pubescens* and *Viburnum nudum.*

The herbaceous cover was similar but considerably less dense and with fewer species than in the stand previously investigated (Table 5). This was probably due to the immature spring growth and the difficulty of identifying grasses and sedges in the vegetative condition. Important species common to

the stands studied in the autumn and in the spring were *Arundinaria tecta, Erianthus giganteus, Erigeron vernus, Eriocaulon decangulare, Panicum longifolium, P. virgatum, Rynchospora gracilenta,* and *Sphagnum spp* (Table 4). A comparison of this list with that for the virgin longleaf pine association shows that no important species is common to the two communities (Table 4). *Aristida virgata, Gymnopogon brevifolius, Panicum angustifolium, P. ciliatum, P. longifolium, P. verrucosum,* and others were not identified in the spring survey although undoubtedly present (Table 4). And there were several species listed in the spring study, not identified in the fall survey such as *Panicum consanguineum, P. scabriusculum* and *P. yadkinense.* The virgin longleaf and cut-over longleaf communities also included many species encountered in the autumn survey but not identified in the spring study. There were also several 'vernal' species not recognizable in the autumn. These facts indicate the necessity of studying any community at least two (and preferably three) times annually, ideally in May, August, and November.

The slash pine-pond cypress community sloped gradually to a slough in

Fig. 4. Slash pine-pond cypress forest streaked for turpentine, autumn, 1935.

which slash pine was associated with the black gum, *Nyssa biflora*. This slash pine-black gum swamp (not studied in detail) corresponds to cver type No. 92 of the Committe on Forest Types but is not listed as occurring in Louisiana. It was characterized by a number of hydric species which contributed very little ground cover. These included *Osmunda regalis, Pluchea purpurascens, Carex glaucescens,* and *Rynchospora corniculata.*

TABLE 4

List of species and average cover degree of species in pineland communities of Southeastern Louisiana.

Species List	Pineland Communities						
	LP Sg.	LP Au.	LP Sp.	CLP Au.	CLP Sp.	P-C Au.	P-C Sp.
Andropogon Elliottii	0.02		0.02	0.42	0.45	0.41	0.09
Andropogon scoparius	0.31	0.50	0.06	0.16		0.61	
Andropogon tener		0.20		0.36			
Andropogon virginicus	0.92	1.64	1.63	2.06	1.44	0.13	0.34
Anthaenanthia rufa						0.05	
Anisostichus crucigera							0.18
Aristida virgata	0.22	0.35	0.61	0.74	0.01	0.25	
Aronia arbutifolia						0.04	
Arsenococcus ligustrinus			0.01				
Arundinaria tecta						0.40	0.42
Ascyrum linifolium	0.01		0.02		0.01	0.04	
Ascyrum stans	0.02	0.01		0.05			
Aster adnatus		0.01	0.05	0.02			
Aster dumosus		0.06		0.49	0.07	0.07	
Aster patens						0.04	
Aster sp.							0.02
Axonopus compressus	0.02	0.16	0.06	0.53	0.86	0.02	0.06
Azalea prinophylla	0.08						
Bidens bipinnata							0.02
Bidens coronata						0.12	0.05
Bignonia radicans		0.01					
Boltonia diffusa		0.01		0.03			
Bradburya virginiana					0.08		
Buchnera americana			0.01	0.01			
Buchnera elongata				0.01			
Campulosus aromaticus					0.02		
Cathartolinum medium		0.02	0.02	0.07		0.05	
Carex glaucescens						0.01	0.02
Carex oblita							0.02
Carex Smalliana							0.02
Centella repanda						0.09	
Cerothamnus carolinensis						0.01	
Chamaecrista littoralis			0.02		0.02		
Chaptalia tomentosa			0.33	0.34	0.06	0.18	
Chondrophora nudata			0.01	0.01			
Cracca ambigua	0.01	0.01		0.05			
Cracca spicata			0.01				
Crotalaria Purshii			0.02				
Crotalaria sagittalis				0.03			
Cyanococcus tenellus	0.02						
Cynoctonum Mitreola				0.02			

Species List	Pineland Communities						
	LP Sg.	LP Au.	LP Sp.	CLP Au.	CLP Sp.	P-C Au.	P-C Sp.
Diodia tetragona				0.18	0.01	0.14	0.02
Diospyros virginiana			0.01				
Drosera brevifolia				0.01			
Drosera intermedia			0.01			0.28	
Eleocharis tuberculosa					0.11	0.05	0.13
Elephantopus nudatus	0.01	0.47	0.30	0.16	0.02	0.07	0.01
Endorima uniflora	0.01	0.01		0.38	0.10	0.01	
Eragrostis Elliottii				0.06			
Eragrostis hirsuta	0.02	0.01					
Eragrostis refracta		0.04		0.04			0.29
Erianthus saccharoides						0.50	0.29
Erigeron vernus		0.01	0.04	0.02	0.04	0.73	0.26
Eriocaulon decangulare				0.04		0.72	0.24
Eryngium Ludovicianum					0.01	0.26	
Eupatorium semiserratum		0.07	0.03	0.44	0.11	0.09	0.01
Fimbristylis autumnalis				0.02			
Fuirena breviseta						0.01	
Gymnopogon brevifolius		0.05	0.03	0.22	0.04	0.02	
Helianthus angustifolius		0.02					
Helianthus heterophyllus				0.11	0.06	0.05	
Helianthus radula			0.16	0.08			
Helenium nudiflorum			0.02		0.01		
Hydrocotyle umbellata					0.01		
Hypericum gymnanthum					0.02		
Hypericum opacum	0.02		0.01		0.02	0.52	0.02
Hyptis radiata						0.01	
Ibidium longilabre				0.02	0.02		
Ilysanthes dubia				0.13			
Juncus aristulatus					0.01		
Juncus dichotomus			0.02		0.01		
Juncus Elliottii					0.02		
Kyllinga brevifolia		0.01					
Lasiococcus Mosieri	0.01					0.01	
Lespedeza repens			0.03		0.02		
Lespedeza sp.			0.05				
Liquidamber Styraciflua	0.12	0.02	0.08				
Lobelia brevifolia		0.01		0.03			
Lobelia floridana					0.03		
Ludwigia linearis				0.01	0.01		
Ludwigia pilosa						0.05	0.03
Lycopodium alopecuroides						0.10	0.13
Lycopus rubellus						0.28	0.08
Manisuris tesselata						0.01	0.18
Meibomia marylandica		0.02	0.02	0.06			
Mitchella repens						0.05	
Nyssa biflora		0.02					
Nyssa sylvatica		0.02					
Oldenlandia uniflora	0.01					0.02	
Onoclea sensibilis							0.02
Osmunda regalis						0.09	0.05
Panicum albomarginatum					0.26		
Panicum angustifolium	0.02			0.70		0.07	
Panicum chrysopsidifolium			0.18		0.29		

Species List	Pineland Communities						
	LP Sg.	LP Au.	LP Sp.	CLP Au.	CLP Sp.	P-C Au.	P-C Sp.
Panicum barbulatum			0.02				
Panicum chamaelonche			0.45				
Panicum ciliatum	0.15		0.10	0.23		0.23	
Panicum consanguineum							0.15
Panicum lanuginosum						0.06	
Panicum leucothrix						0.94	0.03
Panicum longifolium	0.15	0.10		0.22		1.70	
Panicum longiligulatum				0.20			
Panicum lucidum						0.06	
Panicum rhizomatum		0.38	0.30				
Panicum scabriusculum							0.05
Panicum Thurowii			0.02				
Panicum verrucosum		0.10				0.12	
Panicum virgatum						0.94	0.56
Panicum yadkinense							0.54
Panicum sp.	0.48	0.26		0.04			
Paspalum ciliatifolium	0.01		0.01	0.03			
Paspalum circulare					0.03		
Paspalum floridanum		0.15	0.04	0.29	0.26	0.05	0.02
Paspalum laeve		0.02					
Paspalum pubescens						0.09	
Pilostaxis cymosa					0.02		
Pilostaxis ramosa					0.06		
Pinus caribaea (sdlg.)						0.01	0.19
Pinus palustris (sdlg.)		0.01			0.01		
Pinus Taeda (sdlg.)	0.01	0.02	0.20				
Pityopsis graminifolia	0.03	0.01	0.02	0.14	0.02		
Pluchea purpurascens					0.01	0.02	0.16
Proserpinaca palustris				0.02			
Quercus marylandica		0.01					
Rhexia ciliosa						0.05	
Rhexia mariana					0.02		
Rhexia Nashii							0.01
Rubus sp.	0.01					0.06	0.02
Ruellia ciliosa					0.02		
Rufacer Drummondii							0.12
Rynchospora axillaris				0.01		0.04	0.03
Rynchospora Chapmanii						0.01	
Rynchospora compressa						0.01	
Rynchospora corniculata							0.01
Rynchospora cymosa		0.02			0.57		
Rynchospora fascicularis		0.01	0.02	0.15			
Rynchospora gracilenta			0.01	0.17	1.20	0.95	0.81
Rynchospora inexpansa		0.03	0.08	0.10	0.16		0.44
Rynchospora schoenoides				0.01			0.13
Rynchospora Wrightiana				0.89	1.28		0.07
Rynchospora sp.	0.02		0.02				
Sarracenia Sledgei						0.01	
Saururus cernuus						0.01	
Scleria pauciflora				0.05			
Scutellaria integrifolia				0.02		0.01	
Sericocarpus bifoliatus	0.02		0.02	0.02			
Setiscapella subulata					0.01		
Smilax auriculata	0.05						
Smilax pumila	0.01						

Species List	Pineland Communities						
	LP Sg.	LP Au.	LP Sp.	CLP Au.	CLP Sp.	P-C Au.	P-C Sp.
Solidago odora	0.06	0.01	0.02	0.01			
Sphagnum spp. (2)				0.79	0.82	1.56	0.14
Stylosanthes biflora		0.01	0.02		0.01		
Symplocos tinctoria	0.04						
Tamala pubescens						0.32	0.01
Taxodium ascendens						0.01	
Toxicodendron radicans						0.04	0.16
Tragiola pilosa				0.02			
Triadenum virginicum						0.08	
Trilisa odoratissima	0.04	0.01	0.14	0.01		0.02	0.04
Triodia Elliottii		0.01		0.02			
Viola septemloba		0.01					
Viola primulifolia						0.12	0.06
Xyris communis			0.01	0.02			
Xyris fimbriata						0.05	
Xyris Smalliana	0.01	0.01		0.02			
Xyris torta					0.09		

LP, Sg.—Second-growth longleaf pine.
LP, Au.—Virgin longleaf pine (autumn).
LP, Sp.—Virgin longleaf pine (spring).
CLP, Au.—Cut-over longleaf (autumn).
CLP, Sp., Cut-over longleaf (spring).
P-C, Au.—Slash pine-pond cypress (autumn).
P-C, Sp.—Slash pine-pond cypress (spring).

Taxonomic and Ecological Composition

Of the 168 species of plants listed in the pineland communities grasses, sedges, composites, and legumes contributed 55 per cent of the total. Of these four families, grasses were much the most important, not only in number of species (25% of the total) but also in number of individuals, in frequency and in total coverage (Table 4). As a matter of fact the cut-over areas and the herbaceous strata in the virgin forests are 'grasslands' in all important respects except that the trees do control the density of the grasses to some degree. The prairie aspect is further heightened by an abundance of sedges which contributed 12% of the total number of species. The sedges included genera of high frequency and heavy coverage and are therefore of considerable importance in the ecology of these communities.

Although the composites are conspicuous throughout the pineland, they are of little importance as community components. Despite the fact that they contributed 12% of the total number of species only one has a covergrade which would entitle it to the rank of a dominant species. Nevertheless the autumn aspect is so colored by the brilliant flowers of asters, blazing stars, goldenrods, and sunflowers that the unitiated is apt to consider the composites as the principal family. The legumes are less impressive than the composites, not only because their flowers are less conspicuous but also because they contribute only 6% of the species list. None of this family is to be considered as a dominant species in any of the vegetational units studied and no legumes

TABLE 5

Number and covergrade of species in pineland communities of Southeastern Louisiana.

Community	Total-species in community	No. species in quadrats	Average covergrade	Average covergrade per species
Virgin longleaf (autumn) ------	62	46	5.02	0.11
Virgin longleaf (spring) -------	63	50	5.39	0.11
Second-growth longleaf --------	41	33	2.94	0.09
Cut-over longleaf (autumn)-----	80	62	11.59	0.19
Cut-over longleaf (spring ------	53	48	8.79	0.18
Slash pine-cypress (autumn) ----	80	69	14.24	0.21
Slash pine-cypress (spring) -----	56	48	6.72	0.14
Averages ----------	--	--	6.24	0.15

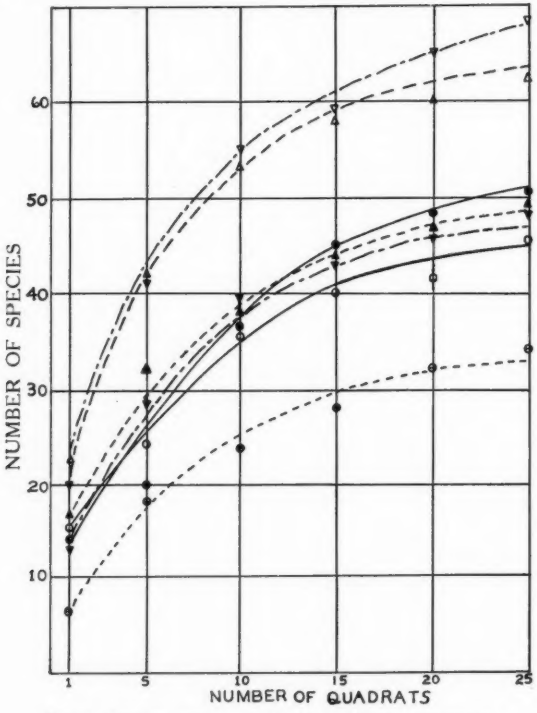


Fig. 5. Species-area curves in the pineland communities.

▽ – – – ▽, Pine-cypress, fall. ▼ – – – ▼, Pine-cypress, spring.
△ — — △, Cut-over lands, fall. ▲ — — ▲, Cut-over lands, spring.
○———○, Virgin longleaf, fall. ●———●, Virgin longleaf, spring.
The lowest curved line in the graph indicates Second-growth longleaf.

whatsoever were encountered in the slash pine-pond cypress swamp (Table 4).

Except for the absence of legumes in the swamp, the communities did not differ significantly in regard to family affiliations. The species content of the communities was somewhat more varied, however. Of the 41 species in the stand of second-growth longleaf pine all but seven were found in the virgin longleaf association and of the 62 species found in the latter, all but twelve were encountered in the cut-over longleaf pine associes (Table 4). There were, however, additional species in the cut-over area which brought the total in the autumn survey to 80 species. Nevertheless the above facts indicate the very close taxonomic and ecological relationships between these three communities. But it was quite otherwise when any one of these three communities was compared with the pine-cypress swamp (Table 4). For example, of the 62 species in the longleaf pine association only 28 were found in the slish pine-pond cypress swamp. Furthermore none of the dominants in the longleaf pine forest was important in the swamp associes. This was due primarily to the hydric nature of the slash pine-pond cypress community.

The number of species was least in the stand of second-growth longleaf pine, somewhat greater in the virgin longleaf pine association and much higher in the cut-over longleaf and slash pine-pond cypress communities. Since the cut-over longleaf and swamp communities also included many hydric species it is probable that the water content of the soil is critical in determining the number of species in the pineland communities. Total coverage followed the same sequence as the number of species but was much higher in the cut-over longleaf and swamp communities than the increase in number of species would suggest (Table 5). Thus the total coverage in the autumn survey was from two to three times that of the virgin longleaf pine association even though the number of species was only 25% greater. The average covergrade per species also followed the same sequence as the total coverage and the total number of species due primarily to the greater number of individuals (Table 5).

An examination of the species-area curves (Fig. 5) shows that new species were added to the species list even up to the last quadrat. This suggests that insufficient quadrats were studied to insure a proper sampling of the community. It has been assumed by investigators that 25 or 50 quadrats of one square meter each were necessary in phytosociological analysis. We believe, however, that for herbaceous vegetation, 15 quadrats of one square meter each, when scattered at a predetermined distance (5-10 meters) apart over the community, constitute adequate sampling. It will be noted that the species-area curves flatten most noticeably at the tenth quadrat. An examination of Table 6 shows that of the total number of herbaceous species in the pinelands, 78% were listed in the first 10 quadrats and 89% were encountered in the first 15 quadrats. Furthermore, although the average covergrade per species was very low (0.15) the average covergrade of those new species encountered in the last 15 quadrats was 0.04 and for the last 10 quadrats only 0.02 (Table 6). Since an herbaceous species must have a covergrade

well above the average (0.15) to be important in a community it is evident that these species must be of little consequence as community components. New species which would be encountered in the last 10 quadrats are best relegated to the extra species list. Since species noted for the first time in the last ten quadrats are characterized by a low frequency and very low cover-grade, it is concluded that 15 quadrats are sufficient for phytosociological analysis, at least in the herbaceous cover of the pineland communities in Southeastern Louisiana.

TABLE 6

Percentage of total species encountered and average cover grade of species in quadrats.

Community	% total species in quadrats.			Average cover grade of species in quadrats.		
	1-10	1-15	1-20	11-25	16-25	21-25
Virgin longleaf (autumn)	80	80	91	.03	.01	.01
Virgin longleaf (spring)	74	92	97	.02	.02	.01
Second-growth longleaf	67	88	97	.04	.04	.01
Cut-over longleaf (autumn)	85	94	98	.07	*.14	.02
Cut-over longleaf (spring)	80	92	96	.02	.02	.01
Slash pine-cypress (autumn)	78	85	91	.07	.02	.02
Slash pine-cypress (spring)	81	92	100	.03	.03	--
Averages	78%	89%	96%	.04	.02	.014

* Omitted from calculations.

Frequency Studies

The herbaceous species in the pineland communities have been arranged in frequency classes on the basis of 25 quadrats one meter square. On this basis the average number of species in the various frequency classes are as follows:—A, 37; B, 8; C, 3; D, 2; and E, 1. Compared to the long period average of Raunkiaer there are too many in class A and too few in Class E. This is true for the 'prairie' in the cut-over area as well as the herbaceous strata in the forests (Table 7). There seems, therefore, to be little difference in the dispersion of herbaceous plants in the forest and in the open pineland community. It will be observed especially (Table 7) that the frequencies of species in virgin longleaf and cut-over longleaf areas are very similar in the autumn, and again in the spring survey, although the frequencies in autumn are quite different when compared with those in the spring. This latter fact again points to the necessity of sampling the community more than once in an annual cycle and to the danger of drawing conclusions from one sampling only.

Various investigators (Cain, 1934) have concluded that the quadrat size which produces frequency curves which most nearly conform to the 'normal spectra' as developed by Raunkiaer and Kenoyer is best suited for the analysis of the particular piece of vegetation investigated. But it is further pointed out that with a larger quadrat size the number of infrequent species (class A) decreases and the number of species in the higher frequency classes increases.

This conforms with our experience. The average percentage of species in the various frequency groups on the bases of 25 quadrats of the one square meter size was 73, 15, 6, 4, 2, whereas it was 50, 21, 13, 7, 9 on the basis of 12 quadrats of 2 square meters each. On the basis of one square meter class A includes too great a percentage of species and class E too few with classes B, C, and D, conforming well to the 'normal' (Table 7). If the quadrat size is doubled the classes more nearly approach the curves of Raunkaier and Kenoyer, although class A has too low and class B too high a percentage of the total number of species. It is probable, therefore, that a quadrat size of one and a half square meters would have given frequency data conforming to the so-called 'normal spectrum.'

TABLE 7

Comparative frequency classes (on basis of 25 quadrats of one sq. meter each) in the pineland communities of Southeastern Louisiana.

	A	> B	> C	$\geq$ $\leq$ D	< E
Virgin longleaf (autumn)	37	3	2	2	1
Virgin longleaf (spring)	38	5	1	3	3
Second-growth longleaf	25	6	0	2	0
Cut-over longleaf (autumn)	40	10	9	2	1
Cut-over longleaf (spring)	33	9	0	3	3
Slash pine-cypress (autumn)	47	11	6	4	1
Slash pine-cypress (spring)	28	11	5	1	0
Average frequency	37	8	3	2	1
Average percentage frequency	73	15	6	4	2
Average percentage frequency (basis 2 sq. m.)	50	21	13	7	9
Raunkiaer's "normal"	53	14	9	8	16
Kenoyer "normal"	69	12	6	4	9

Phenology

The herbaceous plants in the pineland communities come into blossom considerably later than those in communities of the Mississippi Alluvial Plain. There are relatively few species in bloom until May in the piney woods, whereas collecting is good in the alluvial plain as early as March 15. The results in Table 8 were obtained during the month of May but show that relatively few species are in anthesis or in fruit even during this late period. As is to be expected the number of species in flower increases as the summer progresses but the zenith of anthesis is not reached until September. By late October and November, when these studies were made, most of the species were in fruit (Table 8). The percentage of species in flower is listed as 10 and those in fruit as 62. It should be pointed out, however, that more than half of the species listed as in fruit still possessed some flowers, and many plants retained their flowers well into December.

Physical Factors

Our data on physical factors were obtained at about the same time in all the pineland communities in the autumn of 1935. As can be readily seen (Table 9) there was more water as well as more organic matter deeper in the

soil (24″-30″) as compared with the surface layer (0″-6″). Heyward and Barnette (1934) found more organic matter in the first nine inches of soil than was found in our samples from 0″-6″, even in the same communities. As was expected from our observations the water content and amount of organic material was greater in the cut-over longleaf pinelands than in the virgin longleaf forest and was still higher in the slash pine-pond cypress swamp (Table 9).

TABLE 8

Phenological relationships of communities in the pinelands.

	Vegetative	In flower	In fruit
Virgin longleaf (autumn)	10	8	27
Second-growth longleaf (autumn)	16	3	14
Cut-over longleaf (autumn)	14	4	44
Slash pine-cypress (autumn)	20	6	43
Virgin longleaf (spring)	32	16	2
Cut-over longleaf (spring)	25	16	8
Slash pine-cypress (spring)	23	15	10
Percentage of autumn species	28	10	62
Percentage of spring species	55	31	14

The pH of the soil did not vary significantly in the various communities Haas, (1931) found that the pH of the soil in the pine flatlands was highest during the dry weather of the autumn. The data obtained by her were similar to ours. She encountered, however, a range of pH 3.8 to 6.8 during the annual cycle. From observations and our meager physical factor data it seems safe to conclude that pH is relatively unimportant and that water is the critical factor in the distribution of species and communities in the Coastal Plain flatlands of Southeastern Louisiana.

TABLE 9

Physical factor data in the pineland communities.

Community	Water content, % of dry wt.		Organic matter, %		pH	
	0″-6″	24″-30″	0″-6″	24″-30″	0-6″	24-30″
Second-growth longleaf	8.8	10.6	1.16	1.83	5.4	5.2
Virgin longleaf pine	9.5	10.6	0.22	0.50	5.5	5.2
Cut-over longleaf pine	11.6	18.1	1.57	2.13	5.3	5.2
Slash pine-cypress	11.4	19.9	2.40	3.33	5.4	5.4

Note: Each figure represents an average of three samples only.

Summary

1. The results of phytosociological studies in three communities of the pinelands of Southeastern Louisiana are here presented.

2. The virgin longleaf pine association was characterized by a pure, park-like stand of slender, longleaf pine averaging 21.4 inches d.b.h., 107.1 feet high and 210 years old. No shrub stratum was present but grasses, sedges,

and forbs formed a well-developed cover with *Andropogon virginicus, A. scoparius, Aristida virgata, Elephantopus nudatus,* and *Panicum rhizomatum* as the principal species.

3. In the second-growth stand of longleaf pine the trees averaged 12 inches d.b.h., 95 feet high and 93 years of age. Not only was the shrub stratum absent but little herbaceous cover was present. *Andropogon virginicus, A. scoparius, Aristida virgata* and a species of *Panicum* were the only contributors of importance.

4. The cut-over pineland community (pine barrens, savanna) is characterized by the absence of trees and shrubs, except for occasional seedlings, and by a much heavier herbaceous cover than obtained in the longleaf pine forest. *Andropogon virginicus, Aristida virgata, Axonopus compressus, Rynchospora gracilenta, R. Wrightiana,* and *Sphagnum* spp. were the most important components.

5. The slash pine-pond cypress swamp is a hydric community with slash pine usually much more abundant than pond cypress. The slash pine trees averaged 13.8 inches d.b.h., 102.1 feet high, and 135 years of age. No shrub stratum was present but a dense, herbaceous stratum, separable into three layers, concealed the ground. The most important species were *Arundinaria tecta, Erianthus giganteus, Erigeron vernus, Eriocaulon decangulare, Panicum longifolium, P. virgatum, Rynchospora gracilenta,* and *Sphagnum* spp.

6. Grasses and sedges contributed 37% of the 166 species listed in the quadrats in the pineland communities and because of their high frequency, and heavy covergrade are to be considered as the controlling species among the herbaceous plants. The herbaceous species in the second-growth stand of longleaf pine, and in the cut-over longleaf pinelands were similar to those in the virgin longleaf pine forest. This list of species, however, differs significantly from the list obtained in the slash pine-pond cypress swamp.

7. In view of the fact that the species-area curves break most strongly before the 15th quadrat is reached, and since the species encountered after the 15th quadrat have a low frequency and very meager coverage, it is concluded that 15 quadrats are sufficient for a phytosociological analysis of herbaceous vegetation in a community, at least in the pineland communities of Southeastern Louisiana.

8. On the basis of 25 quadrats of one square meter each the average frequency percentages in the various classes obtained were; 75, 15, 6, 4, 2. Compared to the longtime averages of Raunkaier and Kenoyer there is too high a percentage of species in the first class and too low a percentage in the last one. On the basis of quadrats of 2 square meters this is somewhat overcorrected. It is probable, therefore, that a quadrat size of one and a half square meters would have given frequency data conforming to the long period averages.

9. The herbaceous plants in the pinelands blossom but little until May, reach the zenith of anthesis in September, and continue to bloom even into the month of December. Since the species list in the spring differs considerably from that obtained in the autumn it is desirable to sample a community two or three times annually, ideally in May, August, and November.

10. Of the physical factors the water content of the soil is apparently the most critical in the distribution of species and communities in the Coastal Plain flatlands of Southeastern Louisiana.

ACKNOWLEDGEMENTS

The writers gratefully acknowledge the courtesy of the Great Southern Lumber Company of Bogalusa, Louisiana for granting us permission to make studies on their holdings. They also wish to thank Miss Mary Nelson, Mr. Jack Perkins and Mr. Thomas Hall for help in the field work and Mr. Julian Howard for clerical help.

REFERENCES

CAIN, STANLEY A. 1934—A comparison of quadrat sizes in a quantitative phytosociological study of Nash's Woods, Posey County, Indiana. Amer. Midl. Nat. **15**:529-566.

FORBES, R. D. 1930—Timber growing and logging and turpentining practices in the southern pine region. U.S.D.A. Tech. Bull. **204**:1-115.

HAAS, ANNA L. 1931—A study of the vegetation of a cut-over pine area in Louisiana. (Unpublished manuscript).

HAWLEY, R. C. ET AL. 1932—Forest cover types of eastern United States. Washington, D. C.

HEYWARD, FRANK AND R. M. BARNETTE. 1934—Effect of frequent fires on chemical composition of forest soils in the longleaf pine region. Fla. Agr. Exp. Sta. Tech. Bull. **265**:1-39.

HILGARD, E. W. 1860—Report on the geology and agriculture of the State of Mississippi. Pp. 348-351.

PESSIN, L. J. 1933—Forest associations in the uplands of the lower Gulf Coastal Plain (Longleaf Pine Belt). Ecology **14**:1-14.

WAHLENBERG, W. G. AND E. W. GEMMER. 1936—Southern forest ranges. From "The Western Range—A great but neglected natural resource." Senate Document **199**:567-580.

WAKELEY, PHILIP C. 1935—Artificial reforestation in the southern pine region. U.S.D.A. Tech. Bull. **492**:1-115.

TULANE UNIVERSITY,
NEW ORLEANS, LOUISIANA.

Three New Plants from Texas and Mexico and Some Recent Additions to the Texan Flora

Paul C. Standley

During the past few years Field Museum of Natural History has been fortunate in receiving for determination from the University of Texas, through the courtesy of Prof. B. C. Tharp, several important collections of plants made in western Texas and northeastern Mexico by students of the Department of Botany of the University. The Mexican collections have included material of a substantial number of apparently new species, and other specimens that illustrate extensions of range for species already known.

The Texan collections, especially those from the Chisos Mountains, have included material of many rare plants, and several species that probably or certainly are new to the flora of Texas or the United States. There are described below two new species from Texas, besides a new Mexican Polemonium, closely related to the Texan species described. There are listed also several species—only a few of the total number that might be reported—that apparently are not recorded for the flora of the United States.

Amelanchier denticulata (HBK.) Koch—Two Mexican shrubs that have been referred variously to *Cotoneaster* and *Nagelia* constitute a rather distinct and typically Mexican group of the genus *Amelanchier*. *A. denticulata*, although ranging as far north as Chihuahua, has not been recorded from the southwestern United States, but the following collection attests its occurrence in extreme western Texas: Chisos Mountains, August, 1935, Ernest G. Marsh 10. The material is sterile, but apparently quite like Mexican specimens.

Abutilon Marshii Standl., sp. nov.—Ut videtur herba elata erecta, caulibus teretibus dense velutine stellato-pilosis; stipulae filiformes pilosae deciduae c 5 mm. longae; folia majuscula longissime petiolata herbacea, petiolo gracili 7-9.5 cm. longo stellato-piloso; lamina late rotundato-ovata, c. 13 cm. longa atque 10 cm. lata, interdum brevissime triloba, longiacuminata, basi profunde (ad 2 cm.) anguste cordata, sinu fere clauso, in toto margine grosse crenato-dentata, supra grisea densissime molliter stellato-pilosula, subtus albida similiter sed densius stellato-pilosula, basi 7-nervia; flores pauci subterminales et corymbosi, breviter crasse pedicellati, bracteis filiformibus deciduis; calyx 8-9 mm. longus densissime stellato-pilosulus ad medium vel profundius lobatus, lobis lanceolato-ovatis breviter subulato-acuminatis; petala glabra obovata apice rotundata 2 cm. longa 1 cm. et ultra lata venosa.—Texas: Chisos Mountains, August, 1935, Ernest G. Marsh 172 (type in Herb. Field Mus.).

The available material of this plant is, unfortunately, incomplete, and the fruit, so important in segregating species of *Abutilon*, is not represented. However, the species represented seems to be clearly distinct from any of the numerous Mexican ones, nor can it be associated with any of those reported heretofore from Texas.

Polemonium Hinckleyi Standl., sp. nov.—Erecta 40 cm. alta vel ultra, caule simplici vel superne pauciramoso, inferne glabro superne pilis longis albidis laxis eglandulosis sparse villoso, sparse foliato; folia laxa longipetiolata, rhachi anguste alata sparse pilosula; foliola c. 17 sessilia anguste oblongo-lanceolata acuta vel attenuata glabra plerumque 1.7-2.5 cm. longa 3-5 mm. lata; flores pauci terminales vel subterminales laxe corymbosi longipedicellati; calyx campanulatus cum pedicellis dense breviter viscido-pilosus c. 5 mm. longus basi rotundatus, lobis viridibus linearibus apicem versus sensim attenuatis sparse puberulis vel glabris usque 13 mm. longis vel ultra; corolla glabra lutea ut videtur pendens dein patens, tubo angusto 3 cm. longo 3 mm. crasso, superne vix dilatato, lobis ovalibus 8 mm. longis apiculato-obtusis; stamina paullo supra basin tubi affixa, corollam subaequantia.—Texas: Madera Canyon, Mount Livermore, August 6, 1936, L. C. Hinckley 283 (type in Herb. Field Mus.).

The affinity of this probably very local plant is with *P. pauciflorum* Wats., of the Chihuahuan mountains. That species differs in having rather densely villous leaves with more numerous, smaller leaflets, densely villosulous stems, and relatively shorter calyx lobes.

Polemonium stenocalyx Standl., sp. nov.—Radix descendens, caulibus e radice paucis erectis fere 60 cm. altis superne pauciramosis inferne glabris, superne glabris vel pilis paucis albidis laxis conspersis, sat dense foliatis; folia petiolata, rhachi anguste alata sparsissime pilosula vel fere glabra; foliola c. 23 subsessilia tenuia glabra lineari-lanceolata 1.3-2 cm. longa 2-4 mm. lata attenuato-acuta; flores terminales vel subterminales longipedicellati; calyx campanulatus basi obtusus 4-5 mm. longus, pilis paucis longis laxis albidis eglandulosis conspersus, lobis lineari-attenuatis pallidis 10-12 mm. longis glabris; corolla lutea, lobis brunneo-purpureo tinctis, glabra, tubo tereti 2 cm. longo 3-3.5 mm. lato fauce paullo dilatato, lobis 7-8 mm. longis ovalibus apiculato-obtusis; stamina paullo supra basin tubi affixa, corollam subaequantia.—Mexico: State of Nuevo León, below Las Canoas on Cerro Potosí, Municipio de Galeana, scattered on moist arroyo slopes, July 20, 1935, C. H. Mueller 2216 (type in Herb. Field Mus.; duplicate in Herb. Arnold Arb.).

This Mexican plant is a close relative of *P. pauciflorum* and *P. Hinckleyi*, from both of which it differs in the much shorter corolla, as well as in the practically glabrous calyx.

Loeselia scariosa (Mart. & Gal.) Walp.—A rather widely spread species in Mexico, this plant probably has not been recorded from Texas. A recent collection shows that it does extend into the United States in the region of the Rio Grande: Chisos Mountains, August, 1935, Ernest G. Marsh 12.

Eupatorium sphenopodum Robinson.—The species was based upon a Pringle collection from the Sierra Madre near Monterrey, Nuevo León and, so far as I know, has not been reported from other stations. The following Texan collection agrees satisfactorily with the type material: Chisos Mountains, August, 1935, Ernest G. Marsh 149.

Field Museum of Natural History,
Chicago, Ill.

Book Reviews

STRUCTURAL MODIFICATIONS IN THE HAWAIIAN GOOSE (NESOCHEN SANDVICHENSIS), a study in adaptive evolution, by Alden H. Miller. University of California Publications in Zoology, Volume 42, No. 1, pp. 1-80, plates 1-6, 12 figures in text, April 30, 1937.

The dynamic aspect of the comparative anatomy of vertebrates has been increasingly emphasized of late years. Avian anatomists, especially in Germany, have been foremost among the investigators in this field, but in this country ornithologists have given but little attention to such work. The entrance, therefore, of an American into this field, with such a noteworthy paper as this one under review, is especially welcome.

Most of the studies which have appeared have sought to ascertain, through broad surveys of unrelated groups, the fundamental mechanisms subservient to the performance of special functions (e. g., Zimmer on the mechanics of breathing in birds, Böker on types of flight). Miller, however, recognizes, and clearly states, the desirability of comparing closely related groups, since in "widely separated forms, the nature of adaptations may be confused by non-adaptive characteristics peculiar to the different families concerned."

The Hawaiian Goose, *Nesochen*, the most isolated member of the Anatidae, with trends of specialization toward a non-aquatic running and climbing habit, and restriction of flying power, proved to be a most suitable subject for a study of adaptations. The comparative material available to the author, and which provided an adequate basis for the evaluation of adaptive features in *Nesochen*, included specimens of the Emperor Goose *(Philcate)*; Black Brant, Canada Goose and Cackling Goose *(Branta)*; White-fronted Goose *(Anser)*; Snow Goose *(Chen)*; and the South American goose, *Chloëphaga*.

A brief account of the natural history of *Nesochen*, and summaries of the habits of American forms used for comparison, afford a background for the discussion of structural features. Raw data include a detailed comparative description of the muscles of the hind limb, calculations of muscle bulk and relative bulk of individual muscles, and a long list of osteological characters.

Following an analysis of movements of the limb segments in walking and running and in swimming, based on photographs and on observations, the author discusses the role performed by each muscle and each functional group of muscles in these movements, pointing out numerous adaptations in each of the several genera. The concepts of antagonism, synergism, the tendon effect and principles of leverage in muscle action are applied throughout. The treatment follows, in general, that adopted by Howell in *The Anatomy of the Wood-rat*. To my knowledge, this type of analysis has not been applied previously to birds, and Miller's presentation, together with Stolpe's work on joints, now provides a model for future work on the mechanics of the leg in birds.

In considering relationships of the genera, a method of scoring was devised, using 115 differential characters. Judicious use of the results makes possible some tentative conclusions. *Nesochen* is most closely related to the holarctic genus *Branta*; the divergence of the two was in all likelihood an early one. *Branta* represents one main central branch of the Anserinae, with the *Philacte—Chen—Anser* stock representing another branch, *Chloëphaga* still a third. *Chloëphaga* is not closely related to any North American genus; *C. leucoptera* shows evidence of adaptations to upland life that would repay detailed study.

The paper concludes with a synopsis of adaptive evolution in geese, in which are presented the main structural features associated with each of the following four recognizable adaptive trends: adaptation for walking and running; specialization for climb-

ing (not arboreal); increased specialization for swimming, or retention of swimming power with loss of ability on land; increase or decrease in power of flight.

Two principles of general interest, resulting from the study, may be mentioned. First, the modifications in toe length in geese are evidence of heterogonic growth in these parts. Secondly, it is demonstrated that adaptive evolution, in accomplishing certain ends, does not follow precisely the same pathway in each species, even within a single subfamily.—WILLIAM L. ENGELS.

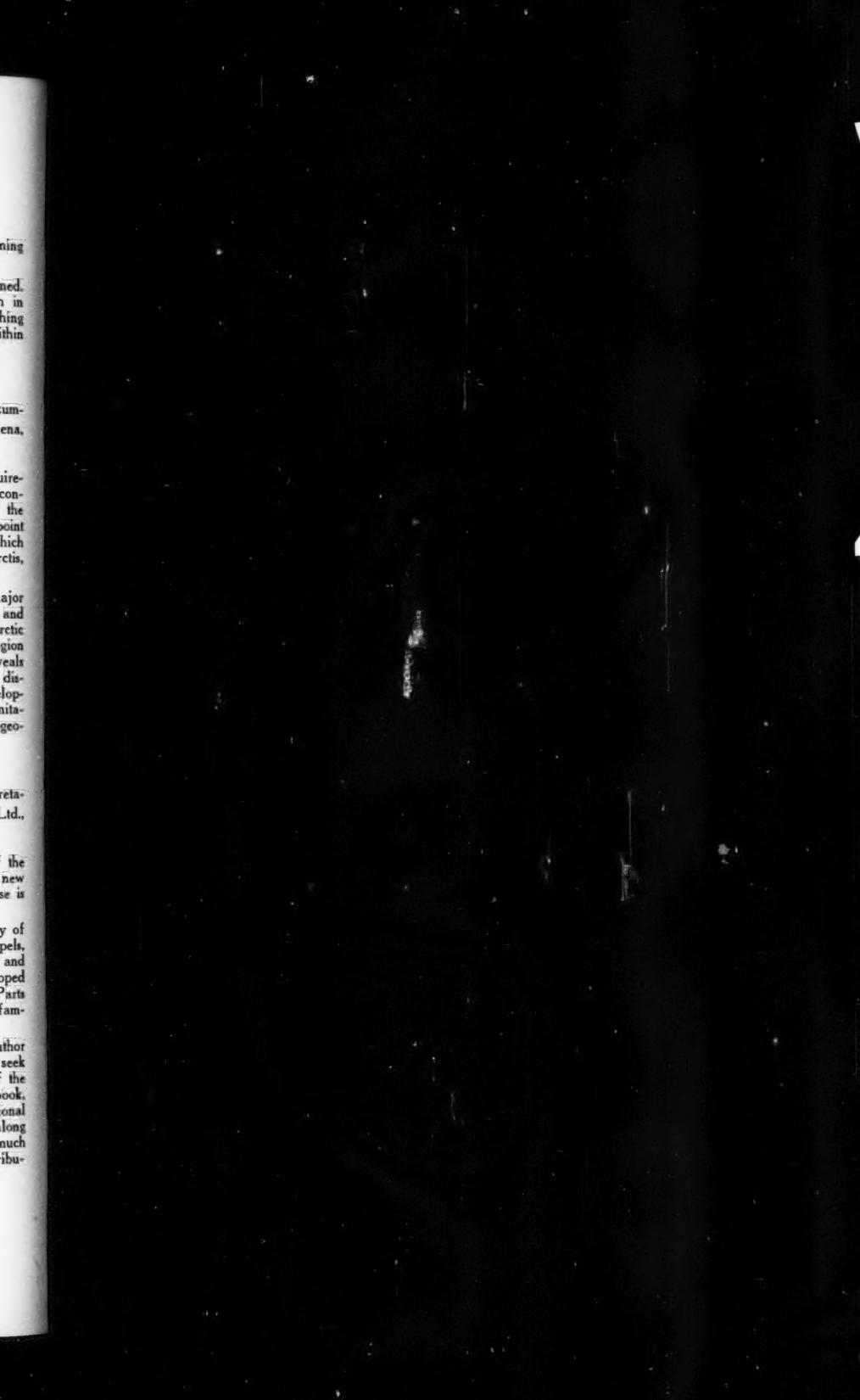
DIE HOLARKTIS. Ein Beitrag zur diluvialen und alluvialen Geschichte der zirkumpolaren Faunen- und Florengebiete. Von W. F. Reinig. Gustav Fischer, Jena, 1937, vii + 124 pp., 19 figs. RM 7,50.

Granting due consideration to the fundamental importance of the ecological requirements of an organism and its ancestors in as much as we may expect these to be constant over long periods the present distribution of organisms is deduced from the history of their habitats. Such an approach, definitely "historical" or "genetic" in point of view, underlies the present treatise on this vast realm (here called holarctis) which is frequently regarded as comprising two distinct regions, i.e. palaearctis and nearctis, respectively.

Following detailed accounts of the holarctic disjuncts, diluvial glaciation, the major glacial refuges, the postglacial areas of invasion, and the recent faunal regions and their origin, two major belts of the holarctis can be distinguished, i.e. 1) the holarctic forest region (more or less continuous), and 2) the holarctic steppe (prairie) region which has a disjunct extension. While the book is not intended as a text it reveals wide acquaintance on the part of the author with biogeographic literature and is distinctly programmatic in character. This is shown by the author's plea for the development of a specific chorologic methodology as a prerequisite for a more precise delimitation of biogeographic regions the world over. In brief a welcome addition to biogeographic literature.—TH. JUST.

FLORAL MORPHOLOGY, a new outlook with special reference to the interpretation of the gynaeceum, by E. R. Saunders. Cambridge, W. Heffer & Sons Ltd., 1937. Vol. 1, viii + 132 pp., 6 figs. Cloth, 3s 6d.

About fifteen years ago when the morphology of the flower, especially that of the gynaeceum, had reached a stage of relative stagnation, Miss Saunders developed a new approach, the essence of which is to be presented in two volumes. The first of these is now available.

The new concepts underlying this volume are known collectively as the "theory of carpel polymorphism" involving the distinction between sterile and fertile carpels, respectively, in syncarpous and pseudo-apocarpous forms. In Part I (introduction and general considerations, pp. 1-23) are set forth the fundamental notions as developed by the author in previous writings (cf. the bibliography on pp. 23-25) whereas Parts 2-4 are given over to a presentation of selected types from various Angiosperm families. There is no index.

The significant subtitle "a new outlook" is no doubt justified as far as the author and her own theory are concerned, yet she gives the reader explicit advice to seek information on the "traditional view" in "existing works on systematic botany." If the reader is willing to limit his curiosity thus he may be served well by this little book, but should he have interest in other "new outlooks" in addition to the "traditional view" he will search in vain for such in this work. Hence a book conceived along broad lines and containing more than a *botanical credo* or *autobiography* is much needed but remains to be written by some one who can see beyond his own contributions.—TH. JUST.